V. V. Sorokin
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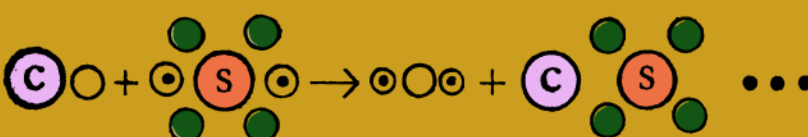
DO YOU KNOW CHEMISTRY?



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This book will help a wide range of users check and improve their knowledge in chemistry. It includes test problems on general and inorganic chemistry presented in popular form. The assignments surve both to check and to enlarge your knowledge. The self-testing technique is conducive to the purposeful study of chemistry, its basic notions and factual material.

The book is intended for higher school and technical school students, as well as for teachers and all those interested in chemistry.

Do You Know Chemistry?

В.В. Сорокин
Э.Г. Злотников

Как ты знаешь химию?

Издательство «Химия» Ленинград

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DO YOU KNOW CHEMISTRY?

Translated from the Russian
by
Irene Bodnya

Mir Publishers, Moscow

First published 1990
Revised from the 1987 Russian edition

На английском языке

Printed in the Union of Soviet Socialist Republics

ISBN 5-03-001380-6

Contents

Preface

The first Russian edition of this book was awarded the first prize from the All-Union Mendeleev Chemical Society in a competition for the best chemistry book for high-school children and chemistry teachers in 1988.

The present book is comprised of assignments in general and inorganic chemistry formulated in the form of a variety of tests. They allow for a self-contained estimation of one's know-how in chemistry. Moreover, this manual can be employed for an advanced study of chemistry.

One of the major goals set by the authors is to teach a student to work independently with the literature on chemistry, to be able to self-estimate his knowledge of the subject, and to develop his initiative and cognition.

The manual performs two functions, controlling and teaching.

The novel feature of the present book resides in the fact that testing assignments are not just separate problems but are complex (i.e. comprising several questions from various fields of chemistry) tests. These are either a selection-type answer or an answer to be formulated independently by a student. In addition, combined tests are also included, which are comprised of problems requiring a constructive answer and choosing an answer as well.

Situations that occur in certain fields of chemistry are given for selection. The alternative answers include also those that are not the subject to be learned. Problems requiring constructive-type answers covèr the basic kinds of cognition and are for those who like chemistry very much. Combined assignments provide a more complete realization of the requirements for the contents and functional validity of a test (see Chapter 5 for the validity concept).

The assignments include subject, logical, and psycological types. There are also included direct and reverse

problems. This enables one to intensify the self-teaching process, using this book, and to instruct one how to employ the knowledge that you possess already and have just acquired in new, unfamiliar situations.

The manual is intended for a wide range of readers who like chemistry and have a great interest in this important field of knowledge. It will be of use for high school students, technical school students, and chemistry teachers.

We are much indebted to Prof. E.M. Sokolovskaya and the members of the Commission on the All-Union chemical competition for high school children for their valuable suggestions.

Finally, our appreciation to Prof. G.A. Krestov (Corr. member of the USSR Academy of Sciences), Prof. N.S. Akhmetov, and associate professor V.A. Rabinovich, whose help is especially valuable to us.

Introduction

Anyone who is learning chemistry may wish to check his knowledge. This can easily be accomplished using test assignments. Such a self-test method favours learning chemistry and excludes the formal approach to mastering the fundamental chemical notions and factual material. Tests not only help realizing the self-control but also allow one to improve and deepen one's knowledge in chemistry, and this in turn develops an interest to this subject and helps using this knowledge in everyday life.

The test is a brief examination, standardized and commonly time-limited. This book presents tests constructed using the material of the subject *chemistry* on the curriculum.

This introduction should be closely considered, as it will help you to use to advantage the whole book.

Don't hurry to look for the answers to the tests. First consider a test attentively and try to answer it yourself. The answer should be looked only for the sake of self-control.

The manual comprises tests with selection-type answers, correlation tests, and tests with independently constructed answers, as well as combined tests in which all of the above variants are used for the answer.

Tests with selection-type answers are provided with sets of alternative answers, among which only one is correct and full. *Correlation tests* presuppose that you should choose appropriate answers for each case. *Tests with an independently constructed answers* are made in such a way as to provide a maximally brief and unambiguous answer.

The notation (...) indicates that one should insert some text which is lacking in the narration or the appropriate formulas of substances, reaction equations, and occasionally the numerical values for the answer. You can find coordination graphs, tables, schemes, and plots

in the manual, which are included to facilitate your work with the manual, understanding of the assignments, and to save your time. You should copy them into your journal where you write the answers.

We recommend that you should consider the tests most attentively, since they contain valuable information for you and may occasionally help in finding the correct answer.

The manual allows checking your knowledge in general chemistry (Chapter 1), inorganic chemistry (Chapter 2), and partly in chemical engineering (Chapter 3). Chapter 4 presents combined tests of all types in various fields of general and inorganic chemistry. These tests are advanced as compared with those included in Chapters 1 through 3. Chapter 5 gives some clues as to the construction of tests, so that you may try and construct some yourself.

The last section of the book contains answers, explanations and solutions to the problems the tests are comprised of. In cases where the answer is quite evident and needs no explanation, the answer provides only its number. In other cases, a brief, sometimes detailed, and occasionally a developed explanation is given.

A set of assignments constructed for specific fields contain simple and intricate tests, which require either only an analysis followed by an answer, or some preliminary calculations and only then an analysis and an answer.

After having solved all the problems in the book you may have an idea as to your know-how in chemistry and decide which sections in the chemistry course you should study in more detail.

And now we wish you good luck!

Chapter 1

Check Your Know-how in General Chemistry

1.1 Law of Chemical Elements

"Presumably, the periodic law will not be destroyed in the future; on the contrary, it will be developed and superstructeo ... ."

D.I. Mendeleev,
July 10, 1905

1. Mendeleev predicted the occurrence of the elements ... and described their theoretical properties in detail.
2. Mendeleev determined theoretically the relative atomic mass of one of the predicted elements using his classification of the elements. As a result, the element had been found to be shifted in the periodic system by two groups. This is ... .
3. Based on his classification of the elements, Mendeleev predicted a certain property of one of the elements more precisely than the scientist who discovered this element. The element is ..., and its discoverer is ... .
4. After the periodic law has been developed, natural families of the elements ... appeared in the periodic table.
5. The isotopes of an element are distinguished by
   (1) the number of neutrons
   (2) the atomic number
   (3) the number of valence electrons
   (4) the number of protons
6. Identify the elements from the number of protons, neutrons, and electrons listed in the table below:

	Number of			Element
	protons	neutrons	electrons	
(1)	14	14	14	...
(2)	24	28	24	...
(3)	70	103	70	...

7. Which of the characteristics of atoms listed below vary periodically?
   (1) Nuclear charge of an atom
   (2) Relative atomic mass
   (3) Number of energy levels in an atom
   (4) Number of electrons in the outer energy level

8. According to the current definition, 1 a.u.m. corresponds to:
   (1) 1/12 mass of carbon-12 atom
   (2) 1/14 mass of carbon-14 atom
   (3) 1/16 mass of oxygen-16 atom
   (4) 1/16 atomic mass of the natural mixture of oxygen isotopes

9. Within the periods from left to right, increasing atomic numbers are commonly accompanied by:
   (1) decreasing atomic radii and increasing electronegativities of atoms
   (2) increasing atomic radii and decreasing electronegativities of atoms
   (3) decreasing atomic radii and decreasing electronegativities of atoms
   (4) increasing atomic radii and increasing electronegativities of atoms

10. Atom of which element loses one electron most readily?
   (1) Sodium, atomic number 11
   (2) Magnesium, atomic number 12
   (3) Aluminium, atomic number 13
   (4) Silicon, atomic number 14

11. Atoms of Group IA elements possess an equal number of:
(1) electrons in the outer energy level
(2) neutrons
(3) the overall number of electrons

12. Which of the elements listed below was called in honour of a country?
(1) In (3) Ra
(2) Si (4) Ru

13. Which of the elements given below was called in honour of a continent?
(1) N (3) Am
(2) Au (4) At

14. In 1886 C. Winkler discovered the element ..., which he called in honour of his homeland. Mendeleev predicted this element in 1871 as ... .

15. The elements are arranged in the order of increasing electronegativities:
(1) As, Se, Cl, F
(2) C, I, B, Si
(3) Br, P, H, Sb
(4) O, Se, Br, Te

16. In periods two and three of the periodic system, with decreasing atomic sizes
(1) the size of their ions also decreases
(2) electronegativity decreases
(3) the metallic properties of the elements diminish
(4) the metallic properties of the elements increase

17. Which sequence includes only transition elements?
(1) Elements 11, 14, 22, 42
(2) Elements 13, 33, 54, 83
(3) Elements 24, 39, 74, 80
(4) Elements 19, 32, 51, 101

18. Period four of the periodic system of the elements contains:
(1) 2 elements (3) 18 elements
(2) 8 elements (4) 32 elements

19. Which of the elements listed below displays chemical properties that make it similar to the element calcium?

(1) Carbon, C
(2) Sodium, Na
(3) Potassium, K
(4) Strontium, Sr

20. The element with an atomic number 114 must exhibit properties similar to those of

(1) platinum
(2) lead
(3) arsenic
(4) mercury

21. Non-metallic properties of the elements that are arranged in the main subgroups of the periodic system are most pronounced in those which occupy

(1) the top of the subgroup
(2) the bottom of the subgroup
(3) the middle part of the subgroup
(4) the whole subgroup from top to bottom

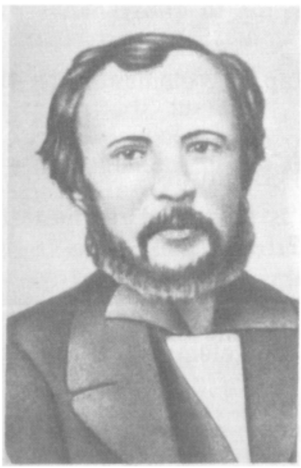
22. The element with an atomic number of 101 was synthesized by the American scientists A. Ghioso, B.G. Harvey, G.R. Choppin, S.G. Thompson, and G.T. Seaborg in 1955. It was named mendelevium in honour of Dmitri Mendeleev, the founder of the periodic table of the elements. He employed the table for predicting the properties of the elements that had not been discovered yet. The discoverers bombarded the target with helium nuclei accelerated in a cyclotron. The isotope ^{258}Md was obtained from the nuclear reaction ... .

D.I. Mendeleev (1834-1907) was the outstanding Russian scientist, educator, and public worker. He became proficient in mathematics and physics, and employed their laws for solving chemical problems. In 1869, Mendeleev discovered the periodic law of the chemical elements as an empirical correlation between the chemical properties of the elements and their atomic weights. Few systematizations in the history of science can rival the periodic concept as broad revelation of the order of the physical world. Mendeleev was the first to effect scientific prognosis in chemistry.

In Mendeleev's treatise *Principles of Chemistry* inorganic chemistry is set forth using the periodic law.

Mendeleev's work became famous during his lifetime. He was an honorary member of a number of Academies of Sciences over the

world, an honorary doctor of many universities, and an honorary member of a great number of scientific societies. His interests were involved in serious investigations in the field of gas theory, petroleum emanation, metrology, etc. Mendeleev's scientific works constitute 26 volumes. In the Soviet Union, a gold medal for outstanding investigations in chemistry in honour of Mendeleev is set up. The USSR Chemical Society bears the name of D.I. Mendeleev.



D.I. Mendeleev

G.N. Flerov

23. The team of scientists headed by Academician G.N. Flerov at the United Nuclear Research Institute in Dubna reported the synthesis of element 104, which was named ... in honour of the Soviet physicist. Element 104 was synthesized by bombarding one of plutonium isotopes with neon nuclei accelerated in the electric and magnetic fields to high speeds. The nuclear reaction for the synthesis is: ... .

Flerov G.N. (b. 1913). A Soviet physicist, Academician (since 1968). His scientific works are in nuclear physics and nuclear chemistry. He discovered (in collaboration with K.A. Petrzhak, 1940) spontaneous fission of uranium-235. In 1962, Flerov discovered spontaneous fission of atomic nuclei from the excited state. In 1953, he headed the works on the synthesis of new heavy transuranium elements.

38. The boiling point for simple substances of the Group VIIA elements, with increasing atomic number

(1) increases
(2) decreases
(3) remains constant
(4) increases and then decreases

39. Which elements yield simple substances that exhibit the most similar physical and chemical properties?

(1) Li, S (3) F, Cl
(2) Be, Cl (4) Li, F

40. Listed below are some elements of period three. Which of them has the most pronounced non-metallic properties?

(1) Aluminium (3) Sulphur
(2) Silicon (4) Chlorine

41. Which element among the Group IIIA elements given below exhibits non-metallic properties most clearly?

(1) Boron (3) Gallium
(2) Aluminium (4) Indium

42. Most typical salts which are composed of only period three elements have the formulas ... .

43. Listed below are elements of period four. Which element offers most pronounced metallic properties?

(1) Zinc (3) Chromium
(2) Copper (4) Potassium

44. Hydrogen was discovered by ... .

45. The mass fraction of hydrogen in a compound with Group IV element is 0.125. The hydride of this element has the formula:

(1) CH_4 (3) GeH_4
(2) SiH_4 (4) SnH_4

46. Which of the period four elements given below exhibits identical valences in its hydride and higher oxide?

(1) Bromine (3) Arsenic
(2) Germanium (4) Selenium

47. From the pairs of simple substances given below, select those which, to your mind, will interact most intensely:

(1) Bi and Br_2
(2) Fe and P_4
(3) Na and Cl_2
(4) Au and I_2

48. The character of the oxides in the series P_2O_5—SiO_2—Al_2O_3—MgO changes

(1) from basic to acidic
(2) from acidic to basic
(3) from basic to amphoteric
(4) from amphoteric to acidic

49. Write the formulas of the higher oxides and corresponding acids of the elements listed below. Name those acids:

	Element	*Oxide*	*Acid*	*Name of the acid*
(1)	N	...	...	...
(2)	P	...	...	...
(3)	As	...	...	...
(4)	Sb	...	...	...

50. Based on the position of the element in the periodic table, write its compounds:

	Element	*Hydride*	*Oxide*	*Hydroxide*
(1)	Ca	...	...	...
(2)	S	...	...	...
(3)	Li	...	...	...
(4)	C	...	...	...

51. Which of the elements Be, B, C, N, Al, Si, P, S, Ga, Ge, As, and Br form oxides of the EO_2 type and which form hydrides of the EH_4 type?

52. Based on the position of the element in the periodic table, derive the formulas for its higher oxide and hydroxide and determine its character:

	Element	*Oxide*	*Hydroxide*	*Character*
(1)	Zn	...	...	...
(2)	Cu	...	...	...
(3)	P	...	...	...
(4)	Sn	...	...	...

53. Write the formulas of the higher oxides for the elements:

	Element	*Oxide*		*Element*	*Oxide*
(1)	Sr	...	(4)	Cr	...
(2)	Pb	...	(5)	S	...
(3)	Mn	...	(6)	Cl	...

54. The element specified by the atomic number 34 forms the hydride ..., higher oxide ..., and hydroxide ... . The last-named compound exhibits:

(1) acidic properties
(2) basic properties
(3) amphoteric properties

55. The higher oxide of an element has the formula EO_3. Its hydride contains 2.47% hydrogen. The element is:

(1) S (3) Te
(2) Se (4) Po

56. Write equations for the reactions between the following substances:

Reactants	*Reaction equation*
(1) Simple substances formed by elements 20 and 15	
(2) Higher oxides of elements 37 and 34	
(3) Hydrates of the higher oxides of elements 4 and 55	
(4) Hydrate of the higher oxide of element 38 and the higher oxide of element 24	...
(5) Hydride of element 34 and the simple substance of element 12	...

57. Which element is most abundant in nature?

(1) Al (3) Mo
(2) Ti (4) W

58. Which element is most abundant in the Solar system?

(1) Oxygen (3) Helium
(2) Hydrogen (4) Carbon

59. In the sixth edition of *Principles of Chemistry* Mendeleev informs the readers about a gas with unusual properties that had been discovered by that moment: "In addition to the well-known constituents of the air, now, owing to the remarkable discovery made in the summer of 1894 by the English scientists Sir Rayleigh and W. Ramsay, a heavy (density abt. 19 if H = 1), inert (like nitrogen) gas must be ranked among the air constituents (up to 1% by volume in the air). It was discovered during the studies of nitrogen density ... . Up till now, this gas was determined together with nitrogen because it combines neither with hydrogen (in eudiometers), nor with copper (during the weight method for determination of the air composition) thus remaining with nitrogen. It was separated from nitrogen on the strength of the fact that magnesium adsorbs nitrogen at red heat whereas this gas is not adsorbed. Its density appears to be one and a half that of nitrogen (can it be nitrogen polymer, N_3?). It is also known that this air constituent exhibits a luminescent spectrum, which contains bright blue lines characteristic of the nitrogen spectrum. Nobody knows the composition and properties of this gas, what compounds it forms, and how to call it because it has just been discovered." Mendeleev wrote about the gas ... .

60. The centenary of the discovery of the periodic law of the chemical elements was marked by all the chemists and the broad public of the world in ... .

1.2 Atomic Structure and Composition of a Substance

"Each substance—from the simplest one to the most complex—exhibits three different but interrelated sides: properties, composition and structure .... The progress of science does not stop after the material carriers of the properties have been discovered. It proceeds farther to elucidate the nature and structure of the carriers found, their composition."

B.M. Kedrov

1. The chemical properties of a substance can be attributed to three fundamental subatomic particles. For two of them, their electrical charges are equal but opposite in sign, and the third particle is electrically neutral. These fundamental subatomic particles are ..., ..., and ... .
2. The number of protons in the nucleus points to the ... of an element and is presented as a left-hand subscript affixed to the symbol of an element. For example, the number of protons for carbon atom can be written as: ... C.
3. The superscript affixed to the symbol of an element indicates the overall number of protons and neutrons in the atomic nucleus and is called ... . The symbol of carbon whose atom contains 6 protons and 8 neutrons in the nucleus is denoted ... C.
4. How many protons, neutrons, and electrons are contained in the atoms of the following isotopes:

	Isotope	*Number of* protons	*Number of* neutrons	*Number of* electrons
(1)	^{13}C	...	...	...
(2)	^{55}Mn	...	...	...
(3)	^{97}Mo	...	...	...

5. The nucleus of krypton-80 atom, $^{80}_{36}Kr$, contains:
(1) $80p$ and $36n$ (3) $36p$ and $80n$
(2) $36p$ and $44\bar{e}$ (4) $36p$ and $44n$
6. The ion of chromium $^{52}_{24}Cr^{3+}$ has
(1) 21 (3) 27
(2) 24 (4) 52 electrons

7. Which species contains more protons than electrons?

(1) Sodium atom
(2) Sulphur atom
(3) Sulphide ion
(4) Sodium ion

8. Given are simple substances: soot, ozone, graphite, Carbyne, oxygen, diamond, and red phosphorus. How many chemical elements constitute these substances:

(1) 3
(2) 4
(3) 5
(4) 6

9. The mass number of an isotope is equal to:

(1) the number of protons in the nucleus of an atom
(2) the number of neutrons in the nucleus of an atom
(3) the number of orbital electrons
(4) the sum of the numbers of protons and neutrons in the nucleus of an atom

10. The atom of an element exhibits the atomic number 13 and the mass number 27. The number of valence electrons is:

(1) 5
(2) 2
(3) 3
(4) 4

11. The outermost electronic shell of an atom of which of the following elements or ions accommodates 8 electrons?

(1) S
(2) Si
(3) O^{2-}
(4) Ne^{+}

12. Which ion has an electronic configuration of a noble gas?

(1) Te^{2-}
(2) Ga^{+}
(3) Fe^{2+}
(4) Cr^{3+}

13. The ion that comprises 18 electrons and 16 protons exhibits the charge:

(1) +18
(2) −18
(3) +2
(4) −2

14. The $3s$ orbital can accommodate a maximum of

(1) 1 (3) 6
(2) 2 (4) 8 electrons

15. The $2p$ sublevel can accommodate a maximum of

(1) 1 (3) 6
(2) 2 (4) 8 electrons

16. The $3d$ sublevel can accommodate a maximum of

(1) 2 (3) 10
(2) 6 (4) 18 electrons

17. Which element is represented by the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$?

(1) K (3) Ba
(2) Ca (4) Na

18. The configuration of electrons in the orbitals of Zn^{2+} ion is:

(1) $1s^2 2s^2 2p^4$
(2) $1s^2 2s^2 2p^6 3s^2 3p^6$
(3) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
(4) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

19. Ne^0, Na^+, and F^- have the same:

(1) mass number (3) number of electrons
(2) number of neutrons (4) number of protons

20. Co^{3+} ion has

(1) 3 (3) 5
(2) 4 (4) 6 unpaired electrons

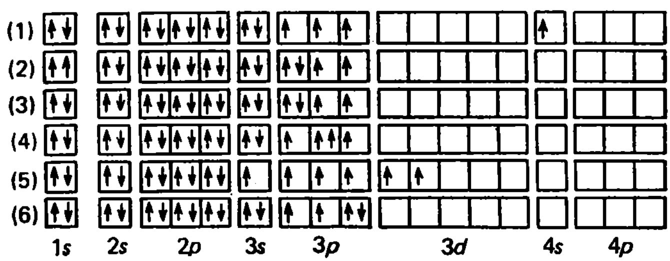
21. Which of the following representations of the orbitals are erroneous?

(1) $2s$, $4f$ (3) $1p$, $2d$
(2) $2p$, $3d$ (4) $1s$, $2p$

22. The element with the atomic number 79 exhibits the following electron distribution over the main energy levels and sublevels: ... .
23. The ground-state atom of which element would you expect to have the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$?

(1) Na (3) Ca
(2) K (4) Ba

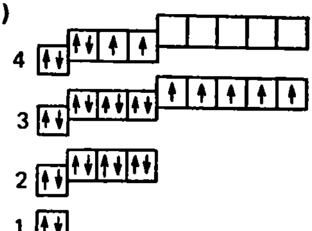
24. These are the electronic configurations of the sulphur atom:



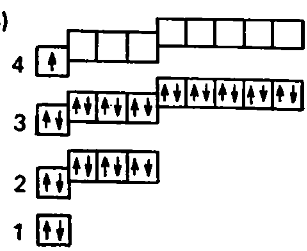
Which of these representations correspond to the ground ..., excited ..., and forbidden ... states?

25. The electrons of the copper atom (atomic number 29) in the ground state are distributed over the orbitals in this manner:

(1)



(3)



(2) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 4s^2$ (4) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$

26. Below you can see the electronic configurations of four atoms. In each case, indicate whether the con-

figuration is that of (I) the neutral atom or of the ion and (II) the ground or excited state:

		Electronic configuration	*I*	*II*
(1)	$_{16}S$	$1s^2 2s^2 2p^6 3s^2 3p^6$	...	...
(2)	$_6C$	$1s^2 2s^1 2p^3$	...	...
(3)	$_{21}Sc$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$	...	...
(4)	$_8O$	$1s^2 2s^2 2p^6$	...	...

27. Which of the following particles has the electronic configuration identical with that of the argon atom?

(1) Ca^{2+} (3) Cl^0
(2) K^0 (4) Na^+

28. For the two ground-state electronic configurations of the atom given below the representation ... is correct

(1)  (2) 

since in the representation ... Hund's rule is violated.

29. Analysis of the ground-state electronic configurations of O^{2-}, F^-, Ne, and Na^+ indicates that the relative sizes of these particles increase in the order ... .

30. Atoms of which elements have the electronic configurations presented below?

	Electronic configuration	*Element*
(1)	$1s^2 2s^2 2p^1$	...
(2)	$1s^2 2s^2 2p^2$	...
(3)	$1s^2 2s^2 2p^5$	...
(4)	$1s^2 2s^2 2p^6 3s^1$	...

31. Which row contains particles arranged in the order of increasing ionic radii?

(1) Mg^{2+}—Cl^-—K^+—Ca^{2+}
(2) Mg^{2+}—Ca^{2+}—K^+—Cl^-
(3) K^+—Ca^{2+}—Cl^-—Mg^{2+}
(4) Ca^{2+}—K^+—Cl^-—Mg^{2+}

32. Which ion possesses the smallest radius (compare the positions of the elements in the periodic system)?

(1) Se^{2-} (3) Rb^{+}
(2) Br^{-} (4) Sr^{2+}

33. Draw the configurations of the outer electronic level for these ions:

	Ion	*Electronic configuration*		*Ion*	*Electronic configuration*
(1)	Mn^{4+}	. . .	(4)	K^{+}	. . .
(2)	S^{2-}	. . .	(5)	Cl^{-}	. . .
(3)	Cu^{+}	. . .	(6)	Pb^{2+}	. . .

34. Which ion has the largest radius? Prove your answer by the position of the element in the periodic system:

(1) Ca^{2+} (3) F^{-}
(2) K^{+} (4) Cl^{-}

35. Which of the ions Cl^{-}, S^{2-}, K^{+}, Ca^{2+} has the smallest radius?

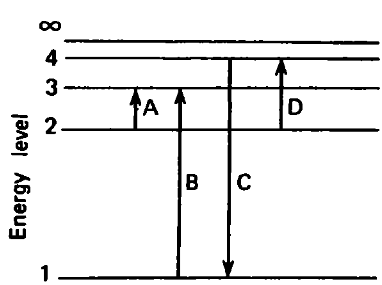
36. Which ion has the smallest radius?

(1) I^{-} (3) Ba^{2+}
(2) Cs^{+} (4) Te^{2-}

37. Do the radii of the atoms in the series K—Ca—Sc—Ti decrease or increase?

38. When an electron in the same atom jumps from a lower energy level to a higher one, energy is absorbed. Which electron transition (see the figure below) results in the absorption of the maximum amount of energy?

(1) A
(2) B
(3) C
(4) D



39. Draw the electronic configurations of manganese exhibiting oxidation states shown below, as well as the formulas for the corresponding oxides:

	Oxidation state of manganese	*Electronic configuration*	*Oxide*
(1)	+2	...	...
(2)	+4	...	...
(3)	+7	...	...

40. The energy indicated in the equation Cl^0 (gas) → Cl^+ (gas) + $\bar{e}$ − 1254 kJ is, for the chlorine atom,

(1) the bond energy
(2) the ionization energy
(3) electronegativity
(4) electron affinity

41. Electron affinity is

(1) the amount of energy needed in removing an electron from an unexcited atom
(2) the ability of the atom of a given element to pull the electron density
(3) the transition of an electron to a higher energy level
(4) the release of energy when an electron is attracted to an atom or ion

42. Which element exhibits the highest ionization energy value?

(1) $_3Li$ (3) $_{26}Fe$
(2) $_9F$ (4) $_{53}I$

43. The energy needed in removing one electron from the atom of an element in the gaseous state for magnesium

(1) is less than that for sodium and greater than that for aluminium
(2) is larger than for sodium and less than for aluminium
(3) is less than for sodium and aluminium
(4) is larger than for sodium and aluminium

44. Starting with the analysis of the electronic configurations for the atoms and the positions of the elements in the periodic table, which atom in the following pairs of atoms exhibits a greater electron affinity?

(1) Potassium or calcium
(2) Sulphur or chlorine
(3) Hydrogen or lithium

45. The chemical elements H, O, F, S, and Cl can be arranged in the order of increasing electronegativities: ... .

46. The chemical elements are arranged in the order of increasing electronegativities in the sequence:

(1) Si, P, Se, Br, Cl, O
(2) Si, P, Br, Se, Cl, O
(3) P, Si, Br, Se, Cl, O
(4) Se, Si, P, Br, Cl, O

47. A and Z denote the mass number and the nucleus charge, respectively. Isotope is

(1) one of two or more atoms whose nuclei have the same A but different Z
(2) one of two or more atoms having different A but the same Z
(3) one of two or more atoms having the same A and the same $A - Z$
(4) one of two or more atoms having different A but the same $A - Z$

48. Consider the electronic configurations of the two neutral atoms

A $1s^2 2s^2 2p^6 3s^1$ and B $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Which of the following statements is erroneous?

(1) Atom A represents the electronic configuration of the sodium atom
(2) Atoms A and B represent different elements
(3) Less energy is needed in removing one electron from atom B than in removing one electron from atom A
(4) The transition from the configuration of atom A to that of the B requires absorption of energy

49. Which row of elements is arranged in the order of increasing atomic radii?

(1) Na, Mg, Al, Si
(2) C, N, O, F
(3) O, S, Se, Te
(4) I, Br, Cl, F

50. In the alkali-metal series (from Li to Cs) cesium is the least electronegative element. This can be accounted for by the fact that it has:

(1) the largest number of neutrons in the nucleus
(2) more valence electrons as compared with the other elements
(3) a higher atomic mass
(4) valence electrons that are most remote from the atomic nucleus

51. Li^+ and H^- ions have isoelectronic structures. Which statement concerning these two particles in the ground (unexcited) state is true?

(1) Li^+ is a stronger reductant than H^-
(2) H^- is larger than Li^+
(3) More energy is needed in removing one electron from H^- than from Li^+
(4) Chemical properties of the two ions are identical, since they have the same electronic structures

$1s^2$ $\boxed{\uparrow\downarrow}$ Li^+ or H^-?

52. The highest penetration effect (during radioactive decay) is observed with:

(1) α-particles
(2) β-particles
(3) γ-rays
(4) thermal neutrons

53. The radioactive decay of radium follows the scheme:

$$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + \ldots$$

and yields, in addition to radon,

(1) a β-particle
(2) a stable lead isotope
(3) a proton
(4) an α-particle

54. γ-Irradiation is the flow of:

(1) helium nuclei
(2) electrons exhibiting equal energies
(3) thermal neutrons
(4) the quanta of electromagnetic radiation

55. The transition ${}^{41}_{20}Ca \rightarrow {}^{41}_{19}K$ involves the transformation of the type:

(1) α-decay
(2) β-decay
(3) electron capture
(4) proton emission

56. Complete the reaction scheme

${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + \ldots$

choosing one of these variants:

(1) ${}^{1}_{1}p$
(2) ${}^{1}_{0}n$
(3) ${}^{2}_{1}H$
(4) ${}^{0}_{-1}e$

57. The nuclear reaction

${}^{27}_{13}Al + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + \ldots$

yields the isotope:

(1) ${}^{25}_{12}Mg$
(2) ${}^{33}_{16}S$
(3) ${}^{29}_{14}Si$
(4) ${}^{25}_{13}Al$

58. An atom of the gold isotope ${}^{197}Au$ contains ... protons, ... neutrons, and ... electrons.

59. Ions having the same number of electrons and an identical structure of the outermost energy level are called isoelectronic ions. The ions O^{2-}, F^{-}, Na^{+}, Mg^{2+}, and Al^{3+} have the electronic configuration of the noble gas neon and are arranged in the order of increasing atomic masses of the elements. Their ionic radii

(1) are almost the same
(2) decrease
(3) increase
(4) decrease and then increase

60. Complex substances ... are characterized by nonpolar molecules.

61. An example of a non-polar molecule possessing a polar covalent bond is

(1) N_2 (3) NH_3
(2) H_2O (4) CCl_4

62. Which substance is characterized by non-polar molecules?

(1) HCl (3) NH_3
(2) CF_4 (4) H_2S

63. Among the molecules H_2, O_2, H_2O, CO_2, CH_4, and H_2S, name polar molecules.

64. Which of the two substances LiH and CsH exhibits a higher ionic character of the chemical bond between the atoms?

65. Which of the four compounds listed below exhibits the highest ionic character?

(1) CCl_4 (liquid) (3) KCl (solid)
(2) SiO_2 (solid) (4) NH_3 (gas)

66. Which compound has a covalent bond between atoms by the donor-acceptor mechanism?

(1) KCl (3) CCl_4
(2) NH_4Cl (4) CO_2

67. Which pair of atoms has a chemical bond exhibiting the most ionic character?

(1) K—F (3) F—F
(2) O—F (4) P—F

68. Complete the scheme presented below by the words "increases" or "diminishes" and point the direction with arrows:

Covalent character of the bond ...

LiF, BeF_2, BF_3, CF_4, NF_3, OF_2, F_2

Ionic character of the bond ...

69. Which pair of elements listed below exhibits the greatest tendency to yield a compound with an ionic bond?

(1) Cu and F (3) Na and F
(2) C and N (4) Li and Ca

70. Which molecule is non-polar?

(1) CCl_4 (3) H_2Se
(2) NH_3 (4) HCl

71. Which compound exhibits a most pronounced polar bond?

(1) Hydrogen sulphide (3) Phosphine
(2) Chlorine (4) Hydrogen chloride

72. The electric moment of the dipole of carbon(IV) sulphide equals zero. The formation of this molecule is described by the ... type of hybridization of carbon atom.

73. Valence orbitals of berillium atom in berillium hydride molecule ... are hybridized to:

(1) *sp* (3) sp^3
(2) sp^2 (4) d^2sp^3

The molecule structure is:

(a) linear (c) tetrahedral
(b) planar (d) octahedral

74. Valence orbitals of boron atom in BF_3 molecule are hybridized to:

(1) *sp* (3) sp^3
(2) sp^2 (4) d^2sp^3

The molecule structure is:

(a) linear (c) tetrahedral
(b) planar (d) octahedral

75. The presence of four equivalent bonds C—H in methane molecule can be attributed to:

(1) the reciprocal repulsion of four electron pairs
(2) the hybridization of carbon atom with the formation of four sp^3 orbitals

(3) the fact that carbon atom has one *s*- and three *p* valence electrons
(4) the fact that carbon atom has two *s*- and two *p* valence electrons

76. Radioactive iodine ^{131}I has a half-life of 8 days. The initial amount of this isotope is 100 mg. How many mg of it will remain after 16 days?

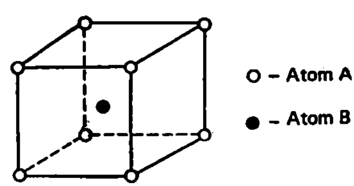
(1) 2.5 mg
(2) 12.5 mg
(3) 25.0 mg
(4) 50.0 mg

77. At an equal temperature and pressure, 1.0 litre of gaseous oxygen and 1.0 litre of gaseous hydrogen have equal:

(1) masses
(2) densities
(3) number of molecules
(4) molecular motion rates

78. The crystalline compound A_xB_y is characterized by a body-centred cell. The compound has the formula:

(1) AB
(2) A_4B
(3) A_8B
(4) AB_4



79. Name the type of a crystal lattice (atomic, molecular, or ionic) for each of the substances given below:

	Substance	*Type of lattice*
(1)	Naphthalene	. . .
(2)	Cesium iodide	. . .
(3)	Sulphur	. . .
(4)	Diamond	. . .
(5)	Rubidium bromide	. . .
(6)	Ice	. . .

80. Which of the substance characteristics mentioned below is the most important for its identification?

(1) Mass
(2) State of aggregation
(3) Volume
(4) Melting point

81. Assuming the same temperature and pressure, the rate of diffusion (penetration into other substances) is the highest for:

(1) hydrogen
(2) nitrogen
(3) oxygen
(4) hydrogen bromide

82. Assuming similar conditions (temperature and pressure), which gas diffuses at the highest rate?

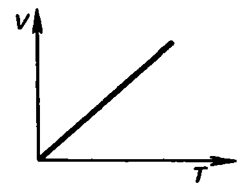
(1) Argon
(2) Nitrogen
(3) Helium
(4) Carbon dioxide

83. Which gas diffuses at the highest rate through a porous membrane (temperature and pressure being the same)?

(1) NH_3
(2) CO_2
(3) NO_2
(4) N_2

84. Which plot is the correct representation of the volume V of the ideal gas as a function of temperature T (at a constant pressure)?

(1)


(3)


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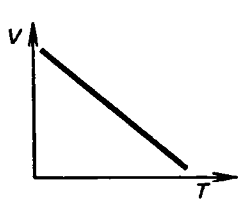

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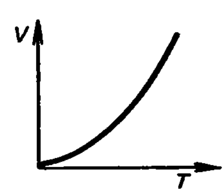


85. Open flasks contain equal volumes of liquids A and B at the same temperature and pressure. Liquid A evaporates at a higher rate than liquid B. Consequently, liquid A exhibits:

(1) a higher density
(2) a greater mass
(3) a higher boiling point
(4) a higher vapour pressure

86. One vessel contains oxygen, the other (of the same volume) carbon dioxide under identical conditions (pressure and temperature). The two vessels contain equal

(1) masses of gases
(2) number of atoms
(3) number of neutrons
(4) number of molecules

87. Four soldered ampoules of equal volume at normal conditions contain bromine, nitrogen, ozone, and helium. The largest number of molecules can be found in the ampoule containing

(1) bromine
(2) nitrogen
(3) ozone
(4) helium

88. 5.0 litres of carbon dioxide at STP contain ... atoms.

89. A substance (density 4 g/cm^3) occupies a volume of 12.0 cm^3. Its mass (g) is:

(1) 0.333
(2) 8.0
(3) 48.0
(4) 4.00

90. At STP the largest number of molecules is contained in one litre of

(1) hydrogen sulphide
(2) water
(3) hydrogen chloride
(4) hydrogen

91. Which of the following groups of substances will be solid at 10 °C?

(1) H_2O, NH_3, CH_4
(2) F_2, Cl_2, Br_2
(3) SO_3, I_2, NaCl
(4) Si, Sb, Hg

92. Which of the substances given below (being in the solid state of aggregation) exhibits the following properties?

(a) Solid substance; exists owing to van der Waals forces; melting point well below room temperature
(b) High-melting solid substance with a reticular structure in which atoms are bonded by covalent bonds
(c) A solid substance that does not conduct electric current; becomes a good conductor when melted
(d) A substance that can form hydrogen bonds

	Substance	*Property*
(1)	Germanium	. . .
(2)	Potassium nitrate	. . .
(3)	Water	. . .
(4)	Methane	. . .

93. A vessel of 50-litre capacity contains equal numbers of oxygen and hydrogen molecules. The pressure in the vessel is 101.3 kPa. Which of the following assertions is erroneous?

(1) Hydrogen molecules move at a faster rate than oxygen molecules
(2) On the average, a greater number of hydrogen molecules collide with the vessel walls per unit time as compared with oxygen molecules
(3) The vessel contains an equal number of moles of each gas
(4) If oxygen is removed from the system, the pressure will diminish to 25.3 kPa

94. Which row contains substances arranged in the order of increasing boiling points?

(1) $BaCl_2$—HF—CO—Ne
(2) Ne—CO—HF—$BaCl_2$
(3) HF—CO—Ne—$BaCl_2$
(4) CO—HF—$BaCl_2$—Ne

95. These hydrogen bonds are arranged in the order of increasing stabilities:

(1) O—H . . . Cl; O—H . . . N; N—H . . . O
(2) N—H . . . O; O—H . . . Cl; O—H . . . N
(3) O—H . . . Cl; N—H . . . O; O—H . . . N
(4) N—H . . . O; O—H . . . N; O—H . . . Cl

96. The coordination number of Mg(II) in crystalline MgO is 6; magnesium oxide can be referred to the structural type of:

(1) rutile
(2) perovskite
(3) sodium chloride
(4) cesium chloride

97. CO_2 molecule is diamagnetic and non-polar. The carbon-oxygen bond is very stable. Bearing in mind that the molecule is linear, the structural formula can be represented as (a solid line denoting a σ bond and a dash line, a π bond):

(1) $O\overset{\sigma}{\underset{\sigma}{=}}C\overset{\sigma}{\underset{\sigma}{=}}O$

(2) $O\overset{\sigma}{\underset{\pi}{=}}C\overset{\sigma}{\underset{\pi}{=}}O$

(3) $O\overset{\pi}{\underset{\pi}{=}}C\overset{\pi}{\underset{\pi}{=}}O$

(4) $O\overset{\sigma}{\underset{\sigma}{=}}C\overset{\pi}{\underset{\pi}{=}}O$

98. Carbon(IV) oxide CO_2 and silicon(IV) oxide SiO_2 have similar chemical formulas of EO_2 type. Their physical properties greatly differ when the oxides are in the solid state, since ... is characterized by the molecular lattice, and ..., by the atomic lattice. Therefore, ... has a high melting point, and ..., a low melting point.

99. The properties of crystalline substances that show various types of chemical bonding differ significantly. These properties are:

(a) low melting point, tendency to sublime, brittleness, lack of electric conductivity
(b) high melting point, brittleness, electric conductivity when melted
(c) high melting point, insignificant electric conductivity (insulating properties)
(d) moderately high melting point, high electric conductivity, malleability, ductility

Choose the characteristic properties for each type of crystal lattice given below:

	Type of lattice	*Properties of substance*
(1)	Ionic	...
(2)	Molecular	...
(3)	Atomic (covalent)	...
(4)	Metallic	...

100. For which molecules is the statement given below correct?

	Statement	C_2H_4	N_2H_4	H_2O_2	H_2F_2
(1)	The bond is covalent between two identical atoms	...	...	...	...
(2)	The molecule contains a double bond	...	...	...	...
(3)	The molecule is planar	...		...	...
(4)	The molecule is polar	...	...	...	...
(5)	The substance contains a hydrogen bond	...	...	...	...
(6)	The substance exhibits basic properties (with respect to water)	...	...	...	...

1.3 Types of Inorganic Compounds

"According to the common properties they possess, the substances may be classed into metals and non-metals, basic and acidic oxides, bases and acids, and salts. These classes of substances are connected genetically ... ."

N.S. Akhmetov
L.M. Kuznetsova
Inorganic Chemistry

1. With what types of inorganic compounds can you classify NaOH, SO_2, Na_3PO_4, and H_2SO_4?

	Type of compounds	*Compound*
(1)	Salts	...
(2)	Bases	...
(3)	Oxides	...
(4)	Acids	...

2. Name the group of these salts: $KHSO_4$, Mg(OH)Cl, K_2NaPO_4, $CaCO_3$.

	Group of salt	*Formula of salt*
(1)	Normal	...
(2)	Acidic	...
(3)	Basic	...
(4)	Double	...

3. Which row includes only acidic oxides?

(1) Na_2O, CaO, CO_2
(2) SO_3, CuO, CrO_3
(3) Mn_2O_7, CuO, CrO_3
(4) SO_3, CO_2, P_2O_5

4. Which of the oxides—MgO, SiO_2, Al_2O_3, NO, P_2O_5, ZnO, and CaO—are capable of reacting with an aqueous solution of sodium hydroxide?
5. Which substance dissolves in water to yield an acid?

(1) NaCl (3) SO_3
(2) CaO (4) NH_3

6. List basic oxides out of the following: SO_3, CrO, P_2O_5, SiO_2, Cl_2O_7, WO_3, and Mn_2O_7.
7. Which row contains only acidic oxides?

   (1) CO_2, SiO_2, MnO, CrO
   (2) V_2O_5, CrO_3, TeO_3, Mn_2O_7
   (3) CuO, SO_2, NiO, MnO
   (4) CaO, P_2O_3, Mn_2O_7, Cr_2O_3

8. The oxides CuO, Al_2O_3, CrO_3, SO_3, Na_2O, ZnO, MnO, and SiO_2 include the following basic oxides: ... .
9. Complete the table, starting from the predominant properties of these oxides: Cr_2O_3, CaO, Cl_2O_7, Na_2O, Al_2O_3, NiO, Mn_2O_7, CrO, P_2O_5, and ZnO.

	Class of oxide	*Oxide formula*
(1)	Acidic	. . .
(2)	Basic	. . .
(3)	Amphoteric	. . .

10. Complete the table below using the names of acids listed here:

   (1) acetic
   (2) perchloric
   (3) hypochlorous
   (4) hydrobromic
   (5) sulphurous
   (6) hydrosulphuric
   (7) diphosphoric
   (8) nitrous

Formula of acid	*Name of acid*	*Formula of acid*	*Name of acid*
HBr	. . .	CH_3COOH	. . .
$HClO$	. . .	H_2S	. . .
H_2SO_3	. . .	HNO_2	
$HClO_4$	. . .	$H_4P_2O_7$	. . .

11. Complete the table below with these names of the bases:

   (1) sodium hydroxide
   (2) calcium hydroxide
   (3) barium hydroxide
   (4) rubidium hydroxide
   (5) iron hydroxide
   (6) copper hydroxide
   (7) aluminium hydroxide
   (8) zinc hydroxide

Formula of base	*Name of base*	*Formula of base*	*Name of base*
$Al(OH)_3$	...	$Ca(OH)_2$	...
$Cu(OH)_2$	...	$Ba(OH)_2$	...
$Fe(OH)_3$	...	$Zn(OH)_2$	...
NaOH	...	RbOH	...

12. Which row contains only amphoteric hydroxides?

(1) $Mn(OH)_2$, $Cr(OH)_2$, $Cu(OH)_2$
(2) $Zn(OH)_2$, $Ba(OH)_2$, $Fe(OH)_3$
(3) $Al(OH)_3$, KOH, $Mg(OH)_2$
(4) $Sn(OH)_2$, $Pb(OH)_2$, $Cr(OH)_3$

13. The sequence ... contains simple substances:

(1) CO, CO_2, H_2O
(2) O_2, H_2, O_3
(3) CH_4, C_2H_4, H_2O_2
(4) SO_2, SO_3, H_2S

14. The molar mass (g/mole) of $Fe(OH)_3$ equals

(1) 73 (3) 104
(2) 75 (4) 107

15. Potassium hydroxide can react with:

(1) Na_2O (3) SO_3
(2) CaO (4) $BaSO_4$

16. Name the salts whose formulas are given below and indicate the salt group (acidic, basic, or normal):

	Formula	*Name*	*Group*
(1)	$NaHSO_4$	...	...
(2)	$(CuOH)_2CO_3$	...	...
(3)	$BaSeO_4$	...	...
(4)	$(FeOH)NO_3$	...	...
(5)	Li_2CO_3	...	...

17. Which oxide has the oxygen mass percent of 50%?

(1) CO (3) SO_2
(2) N_2O (4) CO_2

18. Dilute sulphuric acid can react with

(1) Ag (3) Cu
(2) Fe (4) Pt

19. Which two compounds can react with each other?

(1) CO and NO
(2) CO_2 and HCl
(3) LiH and H_2O
(4) CaH_2 and SiH_4

20. Sodium hydroxide solution will react on heating with

(1) Au
(2) Zn
(3) Cu
(4) Fe

21. Which of the substances listed below cannot react with hydrochloric acid under general conditions?

(1) $CuCO_3 \cdot Cu(OH)_2$
(2) $Cu(OH)_2$
(3) CuO
(4) Cu

22. Which of the following metals will react with concentrated nitric acid without passivation?

(1) Gold
(2) Copper
(3) Iron
(4) Aluminium

23. Which two compounds cannot react with each other?

(1) CaH_2 and H_2O
(2) Na_2O and SO_3
(3) CO_2 and SO_2
(4) MgO and CO_2

24. Magnetite, whose composition is represented by the formula ..., reacts with a solution of hydrochloric acid according to the scheme ... .

25. Potassium hydroxide solution can react with

(1) Ag
(2) Cu
(3) Fe
(4) Al

26. Give formulas of the acidic oxides corresponding to the acids listed below:

	Acid	*Oxide*		*Acid*	*Oxide*
(1)	Carbonic	...	(4)	Nitric	...
(2)	Sulphuric	...	(5)	Selenic	...
(3)	Phosphoric	...	(6)	Arsenous	...

27. How many grams of hydrogen are formed in the reaction between 6.02×10^{22} zinc atoms and sulphuric acid?

(1) 20
(2) 10
(3) 6.5
(4) 0.2

28. Which property is characteristic of aqueous solutions of acids?

(1) Are soapy by touch
(2) Turn litmus solution red
(3) Turn phenolphthalein solution carmine
(4) Turn litmus solution blue

29. Hydrogen evolves intensely during the reaction:

(1) $Zn + HNO_3$ (very dilute)
(2) $Al + NaOH$ (sln)
(3) $Fe + HNO_3$ (conc.)
(4) $S + H_2SO_4$ (conc.)

30. Give the formulas of the salts listed below and indicate the type of each salt (acidic, normal, or basic):

Name of salt	*Formula of salt*	*Type of salt*
(1) Sodium dihydrogen phosphate	. . .	. . .
(2) Ammonium hydrosulphate		. . .
(3) Iron(III) sulphate		. . .
(4) Calcium bicarbonate		. . .
(5) Dihydroxoiron chloride	. . .	. . .
(6) Sodium silicate		. . .
(7) Hydroxocopper carbonate		. . .

31. A vessel with no label on it contains a white substance soluble in water. Its melting point is 776 °C. The substance is

(1) $NaCl$
(2) KCl
(3) $CaCO_3$
(4) $AlPO_4$

32. You need a certain amount of sodium bicarbonate for your experiment. The vessels with reagents show only the formulas of the substances. Which label will you choose?

(1) Na_2CO_3
(2) K_2CO_3
(3) $KHCO_3$
(4) $NaHCO_3$

33. Malachite is calcined in hydrogen to yield:

(1) CuO, H_2O, CO_2
(2) Cu_2O, H_2O, CO_2
(3) Cu, H_2O, CO_2
(4) $CuCO_3$, H_2O, CO_2

34. The simplest coefficients (in the order of writing them) in the equation ... Fe_2O_3 + ... $H_2 \rightarrow$ ... ... Fe + ... H_2O are these:

(1) 2—6—4—6
(2) 1—3—3—2
(3) 2—6—2—3
(4) 1—3—2—3

35. A small amount of sodium hydroxide is added to a test tube containing aluminium chloride. A precipitate formed as a result of the reaction was divided into two portions and transferred to two clean test tubes. A solution of sulphuric acid was added to one of the test tubes, and a solution of potassium hydroxide to the other. The results are as follows:

(1) the precipitates have not dissolved
(2) in the first test tube the precipitate has dissolved, in the second test tube, has not
(3) the precipitate has dissolved in the second test tube, and has not in the first test tube
(4) the precipitate has dissolved in both test tubes

36. Which substance cannot be used for the neutralization of sulphuric acid:

(1) sodium bicarbonate
(2) magnesium oxide
(3) hydroxomagnesium chloride
(4) sodium bisulphate

37. Which compound can be used for the neutralization of sulphuric acid?

(1) HNO_3
(2) $Mg(OH)_2$
(3) CH_3OH
(4) $NaHSO_4$

38. Addition of acid to solution of sodium salts can help to detect the salts in some cases. Which salt cannot be identified in this way?

(1) Na_2CO_3
(2) Na_2S
(3) Na_2SO_3
(4) Na_2SO_4

39. Aluminium hydroxide can be obtained in the laboratory according to the reaction equation ... . Here, the substance ... should be taken in excess.

40. Which reaction can be used for the production of aluminium hydroxide?

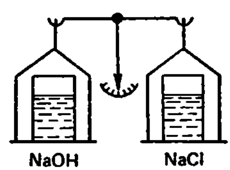
(1) $Al_2O_3 + H_2O \rightarrow \dots$
(2) $AlCl_3 + NaOH$ (excess) $\rightarrow \dots$
(3) $AlCl_3 + NaOH$ (deficit) $\rightarrow \dots$
(4) $Al_2O_3 + NaOH$ (solution) $\rightarrow \dots$

41. A colourless gas is passed through a solution of calcium hydroxide to yield a white precipitate. The gas is:

(1) oxygen
(2) ammonia
(3) hydrogen
(4) carbon dioxide

42. Glasses containing solutions of sodium hydroxide and sodium chloride were put on the pans of the balance. Some time passed and the pointer

(1) deflected to the left
(2) deflected to the right
(3) did not move



43. A small amount of potassium hydroxide was added to a test tube containing a solution of zinc sulphate. The precipitate thus obtained was divided into two portions and placed in two clean test tubes. A solution of nitric acid was added to the first test tube, and a solution of sodium hydroxide, to the second. In the first test tube ... was precipitated, in the second test tube ... was precipitated.

44. Metal from salt is obtained via a number of successive transformations. For example, copper can be produced from copper(II) sulphate through a number of conversions with the following intermediaries:

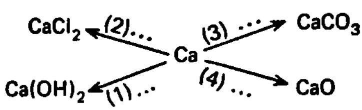
$CuSO_4 \rightarrow \dots \rightarrow \dots \rightarrow Cu$

45. Write equations for the reactions by which the following conversions can be accomplished. Bear in mind that separate conversions can proceed by more than one step:

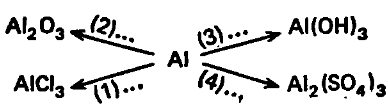
$$FeSO_4 \xrightarrow{(1)\cdots} Fe \xrightarrow{(2)\cdots} Fe_3O_4 \xrightarrow{(3)\cdots} Fe(NO_3)_3$$

46. Which of the oxides BaO, Li_2O, CuO, SO_3, CaO, SiO_2, P_2O_5, Fe_2O_3, Al_2O_3, and Na_2O can react with water?

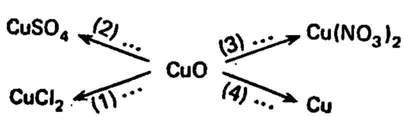
47. Write equations for the following conversions:



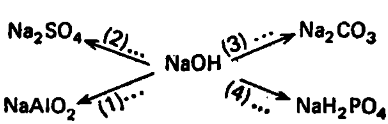
48. Outline, by sequences of equations, the processes by which the following conversions can be made:



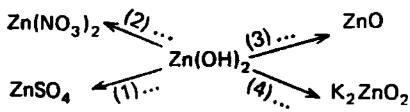
49. Write equations for the reactions to show the conversions:



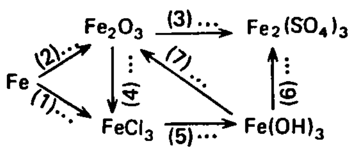
50. Write equations for the following conversions:



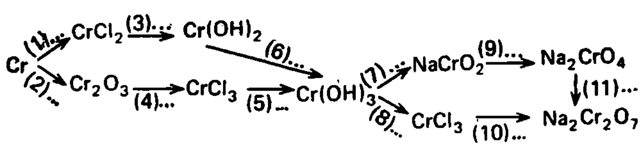
51. Write equations for the reactions describing these conversions:



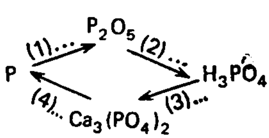
52. Describe the following conversions by reaction equations:



53. Write equations for the conversions:



54. Write equations for the reactions to show the following conversions:



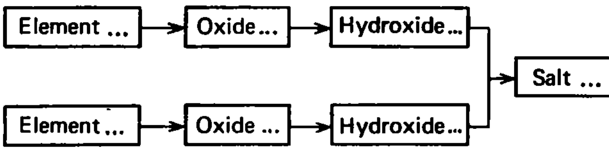
55. Show the pathway of realization of the scheme by

Simple substance → Oxide → Hydroxide → Salt

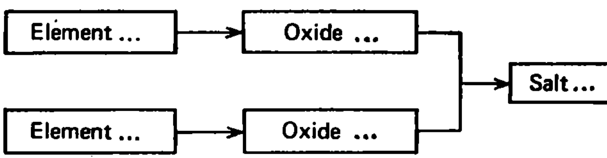
reaction equations using these initial simple substances:

(1) Cu → . . . (3) Ca → . . .
(2) S → . . . (4) C → . . .

56. Based on the scheme below, name two elements (simple substances) starting from which you can obtain two hydroxides which can interact to yield a salt.



57. From the scheme presented below, name a pair of elements (simple substances) that can be used to obtain two oxides which react to yield a salt.



58. Thermal decomposition of which of the salts listed below yields a basic and an acidic oxide simultaneously:

(1) $CaCO_3$
(2) $NaNO_3$
(3) NH_4NO_3
(4) $KClO_3$

59. Complete the schemes of the following chemical reactions:

(1) $\ldots + H_2O \rightarrow NaOH$
(2) $CO_2 + \ldots \rightarrow K_2CO_3 + H_2O$
(3) $FeCl_3 + NaOH \rightarrow \ldots + NaCl$
(4) $Al + H_2O \rightarrow Al(OH)_3 + \ldots$

60. Taking into account the solubilities of oxides in water, which of the reactions whose schemes are given below cannot occur?

(1) $Na_2O + H_2O \rightarrow$
(2) $BaO + H_2O \rightarrow$
(3) $SiO_2 + H_2O \rightarrow$
(4) $SO_3 + H_2O \rightarrow$

1.4 Electrolyte Solutions

"Svante August Arrhenius has received his doctorate for the thesis about 'the galvanic conductivity of electrolytes'. This work and those followed were the foundation for the theory of the electrolytic dissociation which should be considered one of the most crucial achievements of the new science."

M. Jouah

1. Indicate (conventionally) the solubility in water of the substances listed below:

(a) readily soluble
(b) sparingly soluble
(c) nearly insoluble

	Substance	*Solubility*
(1)	Sugar	...
(2)	Silver chloride	...
(3)	Blue vitriol	...
(4)	Common salt	...
(5)	Gypsum	...
(6)	Sodium bicarbonate	...

2. Stepwise dissociation of the acids, bases, and salts given below can be presented in this way:

(1) $H_2SO_4 \rightleftharpoons \ldots$
(2) $Ca(OH)_2 \rightleftharpoons \ldots$
(3) $NaHCO_3 \rightleftharpoons \ldots$
(4) $MgOHCl \rightleftharpoons \ldots$

3. Temperature rise commonly ... the solubility of a solid substance in water, and ... the solubility of a gaseous substance.

4. The crystal hydrate $CaCl_2 \cdot 6H_2O$ weighing 219 g dissolves in 1000 g of water to form a solution characterized by the following mass percent (%) of calcium chloride:

(1) 9.1 (3) 17.9
(2) 11.1 (4) 21.9

5. The solubility of CO_2 in water is independent of:

(1) pressure
(2) temperature
(3) flow rate of the gas
(4) chemical interaction of the gas with water

6. Write equations for the electrolytic dissociation of these strong electrolytes:

(1) $NaOH \rightleftharpoons \ldots$
(2) $Fe(NO_3)_3 \rightleftharpoons \ldots$
(3) $HNO_3 \rightleftharpoons \ldots$
(4) $Ba(OH)_2 \rightleftharpoons \ldots$

7. A solution with a mass percent of sodium hydroxide equal to 6% is prepared by adding the following mass of water (g) to 200 g of a solution with a mass percent of sodium hydroxide of 30%:

(1) 300 (3) 800
(2) 500 (4) 1000

8. The solubility of substances in the sequence AgCl—AgBr—AgI

(1) increases
(2) decreases
(3) is the same
(4) increases and then decreases

9. One litre of a solution containing 0.15 mole of $Mg(NO_3)_2$ also holds the following overall number of moles of Mg^{2+} and NO_3^- ions:

(1) 0.15 (3) 0.45
(2) 0.30 (4) 0.60

10. The sequence ... is arranged in the order of increasing the number of moles of the ions during the dissociation of one mole of salt:

(1) $Fe(NO_3)_3$, $FeCl_2$, $Fe_2(SO_4)_3$
(2) $Fe(NO_3)_3$, $Fe_2(SO_4)_3$, $FeCl_2$
(3) $Fe_2(SO_4)_3$, $Fe(NO_3)_3$, $FeCl_2$
(4) $FeCl_2$, $Fe(NO_3)_3$, $Fe_2(SO_4)_3$

11. Aluminium nitrate solution is

(1) basic
(2) neutral
(3) acidic

12. In the laboratory, solvent can be separated from solute by

(1) decantation
(2) distillation
(3) filtration
(4) sedimentation

13. Which two ions can interact when $AgNO_3$ solution is added to KCl solution?

(1) K^+ and Ag^+
(2) K^+ and NO_3^-
(3) K^+ and Cl^-
(4) Ag^+ and Cl^-

14. Water is heated in a beaker over a heater. The boiling point of the liquid increases if we

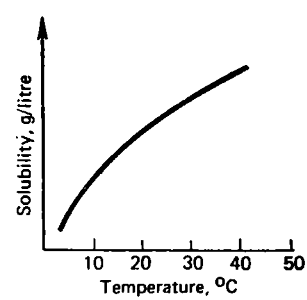
(1) cover the beaker with a lid
(2) enhance the flame of the heater
(3) diminish the flame of the heater
(4) add common salt to the water

15. 5 g of blue vitriol is dissolved in a certain amount of water in a 500-cm^3 flask. Then water is added to the mark. One litre of the solution obtained contains ... moles of copper sulphate.

16. KCl solution was left in a flask. Several weeks passed and a precipitate was formed in the flask. The solution over the precipitate is

(1) dilute
(2) saturated
(3) supersaturated
(4) unsaturated

17. The figure shows a solubility curve for a certain salt. The saturated solution of this salt was obtained at 40 °C. The solution was carefully cooled to 20 °C and a small crystal of the salt was added to the solution. As a result,



(1) the crystal has dissolved
(2) no visible changes have occurred
(3) crystals started to form and grow

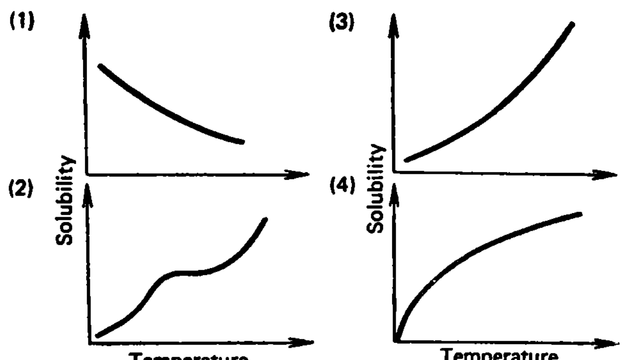
18. The mass (g) of NaOH in 500 cm^3 of a 0.60 *M* solution is

(1) 12 (3) 66
(2) 24 (4) 130

19. The number of KOH moles in 250 cm^3 of 0.2 *M* potassium hydroxide solution is

(1) 0.050 (3) 0.250
(2) 0.045 (4) 0.500

20. Which curve describes the temperature dependence of potassium nitrate KNO_3 solubility in water most correctly?

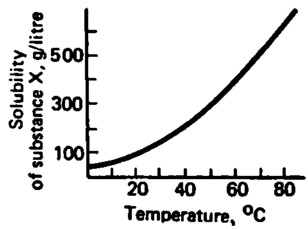


21. Mixed are equal masses of 5% solutions of sodium sulphide and copper(II) chloride. The precipitate formed is filtered off. The mass percent of the substances that remained in the filtrate is ... .

22. The plot shows the solubility of substance X in water as a function of temperature. 50 g of substance X was dissolved in 100 g of water at 100 °C. The

solution was allowed to cool. A saturated solution forms at a temperature (°C) of:

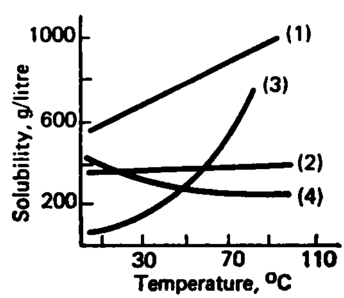
(1) 30
(2) 50
(3) 60
(4) 70



23. In winter, ice-covered roads are sprinkled with NaCl or $CaCl_2$ to make the ice melt. This can be attributed to the fact that:
(1) a solution is formed whose freezing point is higher than that of the solvent
(2) a solution is formed whose freezing point is lower than that of the solvent
(3) heat is evolved
(4) heat is absorbed

24. The solubility of which substance changes the least with temperature rising from 0 to 80 °C?

(1) KBr
(2) NaCl
(3) $K_2Cr_2O_7$
(4) $Ca(C_2H_3O_2)_2 \cdot 2H_2O$



25. Which statement about the properties of seawater is incorrect?

(1) Seawater boils at a higher temperature than fresh water
(2) Frozen seawater melts at a lower temperature than pure ice

(3) The boiling point of seawater increases as it evaporates
(4) The densities of seawater and fresh water are equal

26. Reaction ... is practically irreversible:

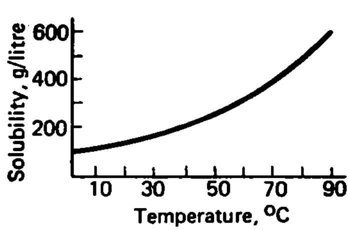
(1) $Na_2SO_4 + KCl \rightarrow \ldots$
(2) $Cr(NO_3)_2 + Na_2SO_4 \rightarrow \ldots$
(3) $NaNO_3 + KOH \rightarrow \ldots$
(4) $H_2SO_4 + BaCl_2 \rightarrow \ldots$

27. The solubility of Na_2CO_3 at 20 °C is 218 g per 1000 g of water. The mass percent (%) of the substance in the saturated solution is:

(1) 8.7 (3) 17.8
(2) 10.6 (4) 21.8

28. Study carefully the solubility curve for substance X presented in the figure. Assuming that the solution was not supersaturated, how many grams of substance X are crystallized out when the hot solution containing 500 g of solute in 1000 g of water is cooled to 40 °C?

(1) 200
(2) 300
(3) 450
(4) 500



29. The crystal hydrate $CoCl_2 \cdot 6H_2O$ weighing 476 g was dissolved in water. The mass percent of cobalt(II) chloride in solution appeared to be 13.15%. The mass of water (g) taken for dissolution of the crystal hydrate was

(1) 500 (3) 1500
(2) 1000 (4) 2000

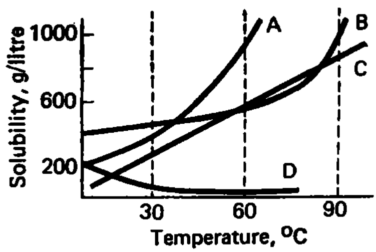
30. One litre of water was mixed with 250 cm³ of a solution having the mass percent of nitric acid equal to

50% (density 1.3 g/cm³). The mass percent (%) of the acid in the solution obtained is:

(1) 10.0 (3) 12.5
(2) 12.2 (4) 16.2

31. Based on the solubilities of substances A, B, C, and D versus temperature presented in the figure, which substance has the highest solubility at 30 °C?

(1) A
(2) B
(3) C
(4) D



32. For the preparation of 10 kg of green vitriol solution with the mass percent of iron(II) sulphate equal to 5%, we need the following amount of crystal hydrate $FeSO_4 \cdot 7H_2O$ (g):

(1) 152 (3) 500
(2) 273 (4) 914

33. Manganese sulphate crystal hydrate contains 24.66% Mn. Its formula is:

(1) $MnSO_4 \cdot H_2O$ (3) $MnSO_4 \cdot 5H_2O$
(2) $MnSO_4 \cdot 4H_2O$ (4) $MnSO_4 \cdot 7H_2O$

34. It has been established analytically that lithium chloride crystal hydrate obtained from a solution contains 7.19% Li. The formula for the crystal hydrate is:

(1) LiCl (3) $LiCl \cdot 2H_2O$
(2) $LiCl \cdot H_2O$ (4) $LiCl \cdot 3H_2O$

35. One mole of soda ash dissolves in water with evolution of heat (25 kJ). Dissolution of one mole of the crystal hydrate is accompanied with the absorption

of heat (67 kJ). The heat of hydration (kJ) of the soda ash is:

(1) + 92 (3) +42
(2) —42 (4) —92

36. One mole of anhydrous calcium chloride dissolves in water with the evolution of heat (76.0 kJ), and the heat of hydration of one mole of calcium chloride is 95.1 kJ. The heat of solution of $CaCl_2 \cdot 6H_2O$ is ... kJ.
37. The heat of solution of one mole of anhydrous copper sulphate is 66.11 kJ. Dissolution of one mole of blue vitriol is accompanied by the absorption of heat (11.5 kJ). The heat of blue vitriol dehydration is ... kJ.
38. The heat of solution of one mole of $Na_2SO_4 \cdot 10H_2O$ is —78.7 kJ, and that of dehydration, —81.6 kJ. The heat of solution (kJ) of anhydrous sodium sulphate is:

(1) +2.9 (3) +160.3
(2) —2.9 (4) —160.3

39. One mole of sodium phosphate Na_3PO_4 is dissolved in water. How many moles of sodium ions are formed after complete dissociation of the salt?

(1) 1 (3) 3
(2) 2 (4) 4

40. One litre of a solution contains 0.1 mole of $FeCl_3$. The overall number of moles of Fe^{3+} and Cl^- ions is:

(1) 0.1 (3) 0.3
(2) 0.2 (4) 0.4

41. The temporary hardness of water is due to the presence of:

(1) $Ca(HCO_3)_2$, $Mg(HCO_3)_2$
(2) $NaHCO_3$, $KHCO_3$
(3) $CaCO_3$, $MgCO_3$
(4) Na_2CO_3, K_2CO_3

42. The temporary hardness of water is eliminated by boiling according to the reaction ... or by adding soda or milk of lime according to the reactions . . . and ... .

43. The permanent hardness of water is due to the presence of:

(1) sulphates and chlorides of sodium and potassium
(2) calcium and magnesium sulphates and chlorides
(3) sodium and potassium carbonates
(4) calcium and magnesium bicarbonates

44. The permanent hardness of water is eliminated by soda according to the reaction ... .

45. Calculate the concentration (mole/litre) of a solution containing 4.0 g of sodium hydroxide in 2 litres of the solution:

(1) 1.0 (3) 0.10
(2) 2.0 (4) 0.05

46. A 200-cm^3 flask contains sodium nitrate solution whose concentration is 0.1 mole/litre. If we pipet out 50 cm^3 of the solution, what is the concentration (mole/litre) of the solution?

(1) 0.2 (3) 0.075
(2) 0.1 (4) 0.025

47. A beaker contains 200 cm^3 of common salt solution with a concentration of 0.10 mole/litre. What is the concentration (mole/litre) of the salt remaining in the beaker after 150 cm^3 of the solution has been removed?

(1) 0.20 (3) 0.075
(2) 0.10 (4) 0.025

48. How many grams of solid sodium hydroxide are needed for the preparation of 50 cm^3 of 0.15 *M* solution?

(1) 0.30 (3) 3.00
(2) 2.00 (4) 20.00

49. How many moles of potassium hydroxide are needed for the preparation of two litres of 2 M solution?

(1) 1 (3) 3
(2) 2 (4) 4

50. What is the molarity of the solution obtained by diluting 250 cm^3 of 3 M solution to 1 litre?

(1) 0.75 (3) 3.0
(2) 1.2 (4) 7.5

51. How many cm^3 of 0.1 M HCl solution can be prepared from 5 cm^3 of 1 M HCl solution?

(1) 30 (3) 50
(2) 40 (4) 60

52. Which of the solutions listed below contains the same number of ions as 1.0 M $CaCl_2$ solution?

(1) 0.5 M $CuSO_4$ solution
(2) 1.0 M $CuSO_4$ solution
(3) 0.5 M Na_2SO_4 solution
(4) 1.0 M Na_2SO_4 solution

53. The molar concentration of sulphate ions SO_4^{2-} in 0.10 M aluminium sulphate solution $Al_2(SO_4)_3$ is equal to:

(1) 0.033 (3) 0.30
(2) 0.10 (4) 0.60

54. 25 cm^3 of HCl solution completely neutralize 50 cm^3 of 2.0 M sodium hydroxide solution. The concentration (mole/litre) of HCl solution equals:

(1) 1.0 (3) 3.0
(2) 2.0 (4) 4.0

55. Which substance dissolves in water to yield a basic solution?

(1) Sodium chloride, NaCl
(2) Hydrogen chloride, HCl
(3) Sodium carbonate, Na_2CO_3
(4) Ammonium chloride, NH_4Cl

56. Assuming complete dissociation of HCl in solution, what is the concentration (mole/litre) of hydrogen ions $[H^+]$ in 0.01 M HCl solution?

(1) 2 (3) 1×10^{-2}
(2) 2×10^{-1} (4) 2×10^{-2}

57. Nitric acid undergoes complete ionization in aqueous solution. The pH of 0.01 M HNO_3 solution is equal to:

(1) 1 (3) 10
(2) 2 (4) 12

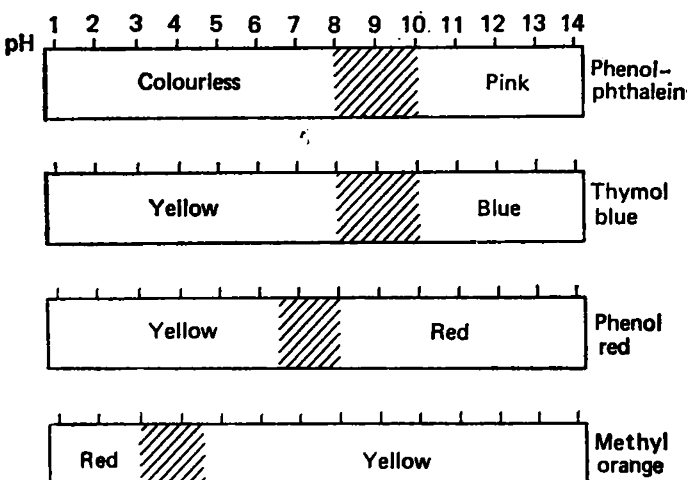
58. The pH of 0.01 M potassium hydroxide solution is:

(1) 0.01 (3) 10
(2) 2 (4) 12

59. An excess acid is added to an alkali solution. The solution pH can change in this manner:

(1) increase from 7 to 8
(2) increase from 3 to 8
(3) decrease from 7 to 6
(4) decrease from 9 to 5

60. The scheme below shows the colour change in the pH ranges for four indicators. Which indicator



will change colour when it is added first to 10^{-3} M and then to $10^{-5}M$ of HCl solutions?

(1) Phenolphthalein
(2) Thymol blue
(3) Phenol red
(4) Methyl orange

61. A solution that is capable of maintaining a nearly constant pH upon addition of small amounts of acid or base is called

(1) acidic (3) neutral
(2) basic (4) buffer

62. Choose the strongest acid out of these listed below:

(1) H_2CO_3 (3) H_3PO_4
(2) H_2SO_3 (4) H_2SO_4

63. The strongest chlorine-containing acid is:

(1) $HClO$ (3) $HClO_3$
(2) $HClO_2$ (4) $HClO_4$

64. The system ... exhibits the most pronounced buffer properties:

(1) HCl and NaCl
(2) NaOH and Na_2SO_4
(3) H_2CO_3 and $NaHCO_3$
(4) H_2SO_4 and K_2SO_4

65. An acidic solution can be prepared by dissolving in water of:

(1) Na_2SO_3 (3) NaH_2PO_4
(2) Na_2HPO_4 (4) Na_3PO_4

66. A basic solution can be obtained by dissolving in water of:

(1) Na_2HPO_4 (3) NaH_2PO_4
(2) $Al_2(SO_4)_3$ (4) $FeCl_3$

67. Complete the table below indicating the solution pH (basic, neutral, or acidic) and writing the equations for salt hydrolysis reactions:

	Substance	*Solution pH*	*Hydrolysis reactions*
(1)	Na_2CO_3	...	...
(2)	$FeCl_3$	...	...
(3)	$CuSO_4$	...	...
(4)	CH_3COONH_4	...	...

68. Aqueous ... solution is acidic:

(1) CH_3COONa
(2) NH_4Cl
(3) Na_2CO_3
(4) Na_2HPO_4

69. Based on the tabulated values of dissociation constants for acids, which acid is the weakest?

(1) Iodic
(2) Carbonic
(3) Phosphoric
(4) Sulphurous

Acid	Dissociation constants		
	K_1	K_2	K_3
HIO_3	1.6×10^{-1}		
H_2CO_3	2×10^{-4}	5.6×10^{-11}	
H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.2×10^{-13}
H_2SO_3	1.7×10^{-2}	6.4×10^{-8}	

70. Hydrolysis of iron(III) chloride solution can be weakened or stopped by adding a little:

(1) hydrochloric acid
(2) potassium hydroxide
(3) solid NaCl
(4) distilled water

71. If the hydrogen ion concentration is increased in solution, then:

(1) the pH value of the solution grows
(2) the hydroxide ion concentration increases
(3) the pH value of the solution decreases
(4) the solution becomes less acidic

72. The solution pH is 5.0. The hydrogen ion concentration (mole/litre) in it equals:

(1) 1.0×10^{-14} (3) 5.0
(2) 1.0×10^{-5} (4) 9.0

73. Which of the acid-base pairs listed below are better suited for maintaining pH 9 unchanged in an aqueous solution?

(1) CH_3COOH-CH_3COO^- (3) NH_4^+-NH_4OH
(2) H_2CO_3-HCO_3^- (4) $H_2PO_4^-$-HPO_4^{2-}

74. Which statement is erroneous?

(1) A solid substance containing Mg^{2+}, Cr^{3+}, and Br^- is soluble in water
(2) A solid substance containing Al^{3+}, K^+, and SO_4^{2-} is soluble in an aqueous solution of sodium hydroxide
(3) A solid substance containing Ag^+, Cu^{2+}, and Cl^- is soluble in an aqueous solution of ammonia
(4) A solution containing Na^+, K^+, and PO_4^{3-} is neutral (with litmus as indicator)

75. Which compounds should be taken to realize the transformation $Cr^{3+} + OH^- \rightarrow Cr(OH)_3$?

(1) $Cr_2(SO_4)_3$, H_2O (3) $CrCl_3$, $NaOH$
(2) Cr_2O_3, HCl (4) Cr_2O_3, $NaOH$

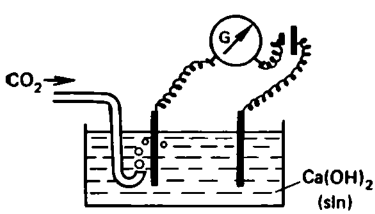
76. Which substance dissolves in water to yield a weakly basic solution?

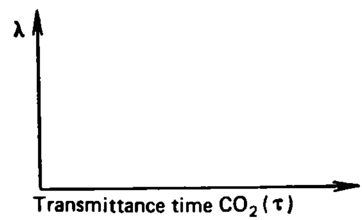
(1) NH_3 (3) SO_2
(2) CO_2 (4) H_2S

77. Which compound should be added to water to increase its pH (7)?

(1) Na_2CO_3 (3) $AlCl_3$
(2) $NaCl$ (4) HCl

78. Carbon dioxide is passed through a calcium hydroxide solution. How will the electrical conductivity λ of the solution change? (It is recorded by a galvanometer, see the figure.)
Plot the dependence.





79. Complete the equation for the hydrolysis reaction:

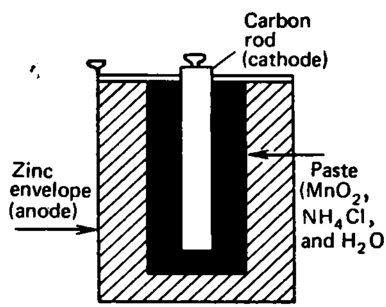
$$\ldots \rightarrow Fe(OH)_2^+ + H^+$$

80. Write the lhs of the reaction equation:

$$\ldots \rightarrow 2Al(OH)_3\downarrow + 3CO_2\uparrow + 3Na_2SO_4$$

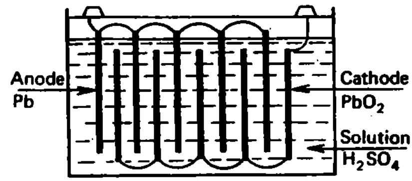
81. The dry cell that you can see in the figure below contains a paste prepared from MnO_2, NH_4Cl, and H_2O used as electrolyte. These electrode reactions proceed:

the anode reaction ...
the cathode reaction ...



82. A lead storage battery (see the figure below) contains sulphuric acid as electrolyte. The discharge of the battery is accompanied by the following electrode reactions:

at the anode ...
at the cathode ...



83. Potassium sulphate (20 g) was dissolved in water (150 cm^3) and electrolysis was carried out, the mass percent of potassium sulphate in solution becoming 15%. The amounts of hydrogen and oxygen evolved were measured at a temperature of 20 °C and a pressure of 101 325 Pa to yield ... and ... litres, respectively.

84. In a galvanic cell made of an iron plate immersed in $FeSO_4$ solution and a copper plate immersed in $CuSO_4$ solution and connected with a salt bridge of saturated KCl solution, the following oxidation-reduction reaction occurs:

(1) $Fe^0 + Cu^{2+} \rightarrow Fe^{2+} + Cu^0$
(2) $Cu^0 + Fe^{2+} \rightarrow Cu^{2+} + Fe^0$
(3) $Fe^{2+} + 2Cl^- \rightarrow Fe^0 + Cl_2$
(4) $Cu^{2+} + 2Cl^- \rightarrow Cu^0 + Cl_2$

85. The investigation of the interaction of zinc and lead with solutions of zinc, iron(II), lead, and copper salts allows concluding whether reactions can occur or not. Mark by the (+) sign the reactions that can occur between a metal and a solution of the corresponding salt. Write the reaction equations.

Metal	Salt solutions			
	Zn^{2+}	Fe^{2+}	Pb^{2+}	Cu^{2+}
Zn		...	...	...
Pb	...	...		...

86. Processes that occur during the electrolysis of nickel sulphate solution are these: at a platinum cathode ... and at a nickel anode ... .

87. Electrolysis of copper nitrate solution yields ... at the carbon cathode, and ... at the carbon anode.

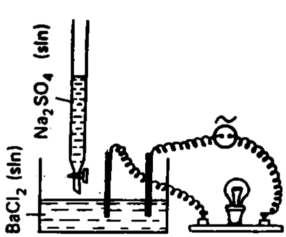
88. Two inert (platinum or carbon) electrodes are immersed in a beaker containing 0.1 *M* $AgNO_3$, $Cu(NO_3)_2$, and $Zn(NO_3)_2$ aqueous solutions. Direct current source being employed, the first to be reduced at the cathode will be:

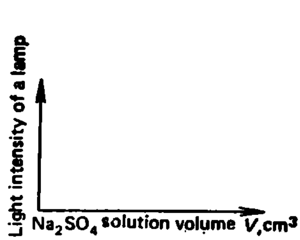
(1) Ag (3) Zn
(2) Cu (4) all three metals deposit simultaneously

89. Electrolysis of an aqueous NaCl solution makes the solution at the cathode:

(1) basic (3) strongly acidic
(2) weakly acidic (4) neutral

90. An experiment was run as follows. 30 cm^3 of 0.1 *M* barium chloride solution was placed in a device for measuring electrical conductivities of solutions. Then the experimentor switched on the device and began adding sodium sulphate solution of the same concentration dropwise from a burette. The bulb in the device was getting dim with every new drop of sodium sulphate solution. Finally, the light went out. Further addition of the solution resulted in a brighter light. The student was recording the experimental data accurately in a log and obtained the following plot:





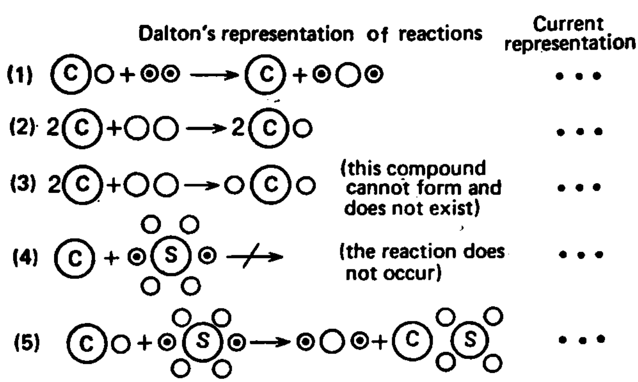
91. The prominent scientist ... was awarded a Nobel Prize in 1903, this being an acknowledgement of the great significance of the electrolytic dissociation theory for the development of chemistry.

1.5 Chemical Reactions Around Us

"... He who loves nature and wishes to experience the deep innermost state of the primary particles the body consists of should search for their properties and changes of, especially, those that chemistry, its nearest servant and confidante, shows, and which can enter the deepest chambers."

M.V. Lomonosov

1. At the beginning of the 19th century the English chemist John Dalton suggested the following graphical representation for the elements:



Write the current representations for the reaction equations given by Dalton.

2. Which parameter always remains unchanged during a chemical reaction?

(1) Mass
(2) Volume
(3) Pressure
(4) Concentration

3. The processes:

(1) combustion of magnesium band
(2) drawing of copper wire
(3) fractionation of crude oil
(4) evaporation of water from the surface of a water basin
(5) dulling of silver articles
(6) formation of green film on a copper candlestick
(7) nail corrosion
(8) carbon combustion
(9) dissolution of sugar in water
(10) ozone formation in the atmosphere during thunderstorms include physical processes (...) and chemical processes (...).

4. In the course of a chemical reaction:

(1) the overall mass of substances remains constant
(2) molecules of substances entering into a reaction survive
(3) atoms of substances entering into a reaction survive
(4) the overall number of atoms before the reaction equals that after the reaction

The statement ... is incorrect.

5. A clean iron nail is placed in a blue solution of copper(II) chloride. The nail is quickly covered with copper film. The solution turns greenish. The chemical process ... is classed with the reactions of:

(1) decomposition
(2) addition
(3) replacement
(4) exchange

6. The reaction $H_2SO_4 + 2KOH = K_2SO_4 + 2H_2O$ is that of

(1) reduction
(2) hydrolysis
(3) oxidation
(4) neutralization

7. Complete the table below choosing one of these types of reactions:

(a) combustion
(b) precipitation
(c) neutralization
(d) oxidation-reduction

	Reaction	*Type*
(1)	$Pb(NO_3)_2 + Na_2CrO_4 = PbCrO_4\downarrow + 2NaNO_3$	...
(2)	$Fe + 2HCl = FeCl_2 + H_2\uparrow$	...
(3)	$CH_4 + 2O_2 = CO_2 + 2H_2O$	...
(4)	$NaOH + HCl = NaCl + H_2O$	...

8. Reaction ... involves no change in the oxidation states of the elements:

(1) $4P + 5O_2 = 2P_2O_5$
(2) $CaO + H_2O = Ca(OH)_2$
(3) $2NaNO_3 = 2NaNO_2 + O_2\uparrow$
(4) $Fe + H_2SO_4 = FeSO_4 + H_2\uparrow$

9. Reaction ... involves a change in the oxidation states of the elements:

(1) $MnO_2 + 4HCl = MnCl_2 + Cl_2 + 2H_2O$
(2) $NaCl + H_2SO_4 = NaHSO_4 + HCl$
(3) $SO_2 + H_2O = H_2SO_3$
(4) $Na_2O + SO_3 = Na_2SO_4$

10. A disproportionation reaction is characterized by an increase and a decrease in the oxidation state of atoms of the same element. Reaction ... does not belong to this type of reaction:

(1) $2NO_2 + H_2O = HNO_3 + HNO_2$
(2) $Cl_2 + H_2O = HCl + HClO$
(3) $3K_2MnO_4 + 2H_2O = 2KMnO_4 + MnO_2 + 4KOH$
(4) $2FeSO_4 + 2H_2O = (FeOH)_2SO_4 + H_2SO_4$

11. Which of the reactions given below is a substitution reaction?

(1) $Fe + O_2 \xrightarrow{T} \ldots$
(2) $Fe + HCl \rightarrow \ldots$
(3) $Fe + Cl_2 \rightarrow \ldots$
(4) $FeCl_2 + AgNO_3 \rightarrow \ldots$

12. Which reaction is an addition reaction?

(1) $KOH + HCl \rightarrow \ldots$
(2) $Na_2CO_3 + H_2SO_4 \rightarrow \ldots$

(3) $CaCO_3 \xrightarrow{T} \ldots$
(4) $CaO + H_2O \rightarrow \ldots$

13. An oxidation-reduction reaction is presented here by this skeleton equation:

(1) $KOH + HCl \rightarrow KCl + H_2O$
(2) $CaCO_3 \xrightarrow{T} CaO + CO_2$
(3) $2HgO \xrightarrow{T} 2Hg + O_2\uparrow$
(4) $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2\uparrow + H_2O$

14. The reaction equation

$H_2SO_4 + 2NaOH = Na_2SO_4 + 2H_2O$

characterizes the following process:

(1) decomposition
(2) oxidation-reduction
(3) neutralization
(4) combination

15. Which of the processes listed below is slow oxidation?

(1) Magnesium combustion in the air
(2) Gasoline ignition
(3) Iron corrosion
(4) Explosion of a hydrogen/oxygen mixture

16. Complete these skeleton equations:

(1) decomposition, $Fe(OH)_3 \rightarrow Fe_2O_3 + \ldots$
(2) combination, $Fe + \ldots \rightarrow Fe_2O_3$
(3) substitution, $Fe + \ldots \rightarrow FeSO_4 + \ldots$
(4) exchange, $FeCl_3 + \ldots \rightarrow Fe(OH)_3 + \ldots$

17. Based on the solubility of the substances, which reaction involves no precipitation?

(1) $MnSO_4 + Na_2S \rightarrow \ldots$
(2) $AgNO_3 + NaCl \rightarrow \ldots$
(3) $CuCl_2 + NaOH \rightarrow \ldots$
(4) $FeS + HCl \rightarrow \ldots$

18. Combustion of iron in oxygen yields iron scale Fe_3O_4. Which statement is wrong?

(1) The reaction equation is

$3Fe + 2O_2 = Fe_3O_4$

(2) Fe_3O_4 consists of seven atoms
(3) This process is spontaneous
(4) The mass of the reactants is equal to the mass of the reaction products

19. Reduction occurs when

(1) neutral atoms convert into negatively charged ions
(2) neutral atoms convert into positively charged ions
(3) the positive charge on the ion increases
(4) the negative charge on the ion decreases

20. A turned over beaker wetted with limewater was held over the flame of a candle. A white film of the composition ... appeared on the beaker wall because the reaction ... occurred.

21. Hydrogen peroxide H_2O_2 can be an oxidizing agent and a reducing agent as well. The oxidation and reduction processes can be presented by the following equations:

(a) $H_2O_2 + 2H^+ + 2\bar{e} \rightarrow 2H_2O$
(b) $H_2O_2 - 2\bar{e} \rightarrow O_2 + 2H^+$
(c) $H_2O_2 + 2\bar{e} \rightarrow 2OH^-$
(d) $H_2O_2 + 2OH^- - 2\bar{e} \rightarrow O_2 + 2H_2O$

H_2O_2 acts as a reducing agent in

(1) a, b (3) a, c
(2) c, d (4) b, d

22. Which metal should not be used as an active electrode for the cathodic protection of the steel hull of a ship?

(1) Mg (3) Al
(2) Cu (4) Zn

23. Carbon combustion under the conditions of oxygen deficiency yields an extremely toxic gas (carbon monoxide) according to the reaction equations ... .
24. Sounding balloons are commonly filled with hydrogen obtained in the reaction between calcium hydride and water ... .

25. Write the lhs of the reaction equation:

$$... = 2MnSO_4 + 6K_2SO_4 + 3H_2O$$

26. In the reaction

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$$

(1) hydrogen is reduced in H_2SO_4
(2) hydrogen is oxidized in H_2SO_4
(3) sulphur undergoes reduction in H_2SO_4
(4) sulphur undergoes oxidation in H_2SO_4

27. In the course of the reaction

$$Cr_2S_3 + KNO_3 + Na_2CO_3 \rightarrow K_2CrO_4 + NO + CO_2 + Na_2SO_4$$

these elements undergo oxidation:

(1) N, S
(2) S, Cr
(3) C, N
(4) Cr, N

28. In the reaction

$$As_2S_3 + 28HNO_3 \text{ (conc.)} = 2H_3AsO_4 + 3H_2SO_4 + 28NO_2 + 8H_2O$$

elements ... undergo oxidation.

29. Right the lhs of the reaction equations:

$$... = 2CrCl_3 + 3Cl_2 + 2KCl + 7H_2O$$
$$... = K_2SO_4 + 2MnSO_4 + 5S + 8H_2O$$

30. The sum total of the coefficients in the rhs of the reaction equation

$$KMnO_4 + HCl \rightarrow MnCl_2 + KCl + H_2O + Cl_2$$

equals

(1) 4 (3) 17
(2) 8 (4) 18

31. Oxidation of Fe^{2+} to Fe^{3+} yields reduction of potassium permanganate in the acidic solution to a manganese salt with an oxidation state of +2. How many moles of iron(II) sulphate are oxidized with one mole of potassium permanganate?

(1) 1 (3) 10
(2) 2 (4) 5

32. In the reaction

$Cr_2S_3 + Mn^{2+} + NO_3^- + CO_3^{2-} \rightarrow CrO_4^{2-} + MnO_4^{2-} + NO + CO_2 + SO_4^{2-}$

these elements undergo oxidation:

(1) Mn, N, S (3) C, S, Cr
(2) Mn, S, Cr (4) Cr, S, N

33. In 1840, Germain Hess, chemistry professor of St. Petersburg Mining Institute formulated the fundamental law of thermochemistry (the law of constant heat summation), which states that the net amount of heat liberated or absorbed in a chemical reaction is the same regardless of the path by which the change occurs.
The important corollary to the law reads:

(1) the heat of a chemical reaction is equal to the heats of formation of the initial reactants
(2) the heat of a chemical reaction equals the heats of formation of the reaction products
(3) the heat of a chemical reaction is equal to the net heat of formation of the products minus the net heat of formation of the initial reactants
(4) the heat of a chemical reaction is equal to the sum of heats of formation of the products and heats of formation of the initial reactants

Germain Ivanovich Hess (1802-1850) was a German-born Russian chemist, member of the St. Petersburg Academy of Sciences, and a founder of thermochemistry. In 1840 he discovered the fundamental law of thermochemistry. Hess discovered and determined the composition of a number of new minerals and suggested a technique for producing tellurium from silver telluride, which was named *hessite* in his honour.

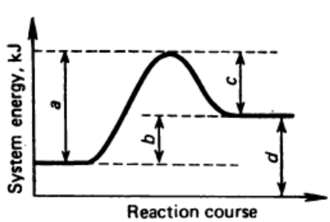
34. Classify these processes:

(1) discharge of a battery of an electronic flash
(2) ice melting
(3) evaporation of alcohol
(4) sodium-water interaction
(5) lightning discharge
(6) dissolution of concentrated sulphuric acid in water
(7) phosphorus combustion in the air
(8) slaking of quick lime

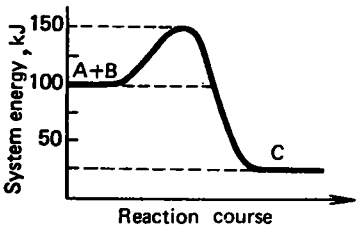
into exothermic and endothermic processes.

35. Which portion of the plot indicates the value of the heat of reaction?

(1) a
(2) b
(3) c
(4) d



36. By means of the energy plot given below, find the heat of the reaction A + B → C (in kJ).



37. Thermochemical equation for the carbon combustion reaction is

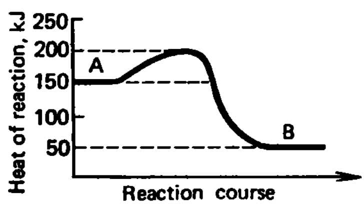
$C + O_2 = CO_2 + 402.24$ kJ

In the course of the reaction, 167 600 kJ was released. How many grams of carbon were burned?

(1) 500
(2) 1000
(3) 4000
(4) 5000

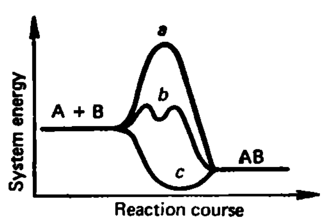
38. Heat of conversion of substance A to substance B is equal to (kJ):

(1) −50
(2) +100
(3) −150
(4) +200



39. The exothermic reaction between substances A and B is presented in the plot below. Catalyst-induced preparation of substance AB follows the pathway

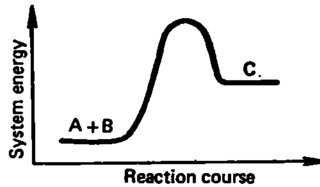
(1) a
(2) b
(3) c



(4) catalyst produces no effect on the course of the reaction

40. Based on the plot given below, describe the reaction $A + B \rightarrow C$:

(1) the reaction rate is very high
(2) the reaction is exothermic
(3) the reaction is endothermic
(4) the plot indicates the equilibrium state



41. The rate of a one-step reaction $2A + B \rightarrow C$ can be defined by the following equation:

(1) $v = k[B]$
(2) $v = k[A]^2$
(3) $v = k[A][B]$
(4) $v = k[A]^2[B]$

42. The mechanism of the reaction $A + 2B \rightarrow 2C$ can conventionally be described by the following steps:

(a) $A + B \rightarrow K + E$
(b) $B + K \rightarrow M$
(c) $B + E \rightarrow D$
(d) $M + 2D \rightarrow 2C$

Assuming that step (a) is the slowest and step (d) the quickest, which expression can be used to determine the reaction rate?

(1) $k([M][D]^2 - [A][B])$
(2) $k[A][B]^2$
(3) $k[M][D]^2$
(4) $k[A][B]$

43. Based on the experimental evidence tabulated below, write the equation for the rate of the reaction $2A + 3B \rightarrow 3C + 2D$ (the temperature for all the runs was the same)

	Runs I	II	III
Initial concentration of A, C_A mole/litre	0.10	0.20	0.20
Initial concentration of B, C_B, mole/litre	0.10	0.10	0.20
Rate of the forward reaction, v, mole litre^{-1} s^{-1}	0.01	0.04	0.04

In compliance with these data, the rate equation for the above reaction reads ....

44. The reaction A_2 (gas) + B_2 (gas) = 2AB (gas) occurs in a gas phase, A_2 and B_2 molecules colliding. If the concentrations of the reactants A_2 and B_2 are increased two-fold while the other conditions remain unchanged, the reaction rate will increase by a factor of

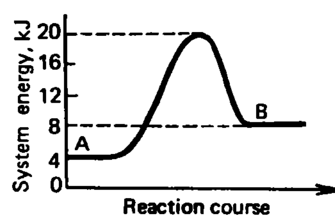
(1) $\sqrt{2}$ (3) 3
(2) 2 (4) 4

45. In the reaction between zinc and hydrochloric acid, a zinc cube of 1 g mass was reduced into 1000 equal cubes. The volume of the evolving hydrogen will

(1) remain unchanged
(2) increase about 10 times
(3) increase by a factor of about 100
(4) increase about 1000 times

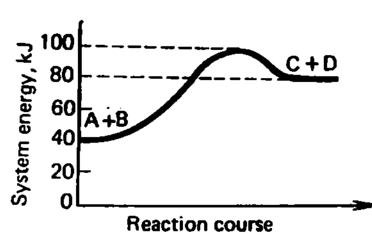
46. Examine the plot given below and make a conclusion about the numerical value of the activation energy of the conversion of A to B (kJ/mole):

(1) +16 (3) +8
(2) +12 (4) +4



47. Find the activation energy (kJ/mole) for the reaction
A (gas) + B (gas) → C (gas) + D (gas)
from the plot given below:

(1) 20 (3) 60
(2) 40 (4) 80



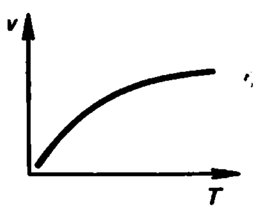
48. Catalyst speeds up a chemical reaction because it

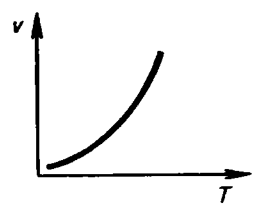
(1) lowers the activation energy
(2) increases the activation energy
(3) increases the reaction heat
(4) decreases the reaction heat

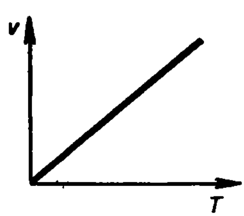
49. A catalytic reaction occurs when

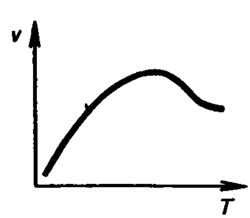
(1) the rate of hydrogen-bromine interaction increases on heating
(2) the intensity of carbon combustion increases after its grinding
(3) the rate of hydrogen peroxide decomposition increases after manganese dioxide is introduced into it
(4) the rate of phosphorus combustion increases when it is placed in pure oxygen

50. Which curve corresponds to the temperature dependence of the rate v of a simple one-step reaction?

(1)


(3)


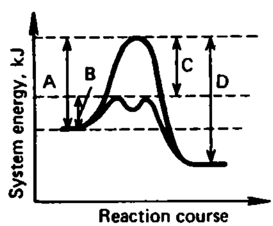
(2)


(4)


51. Construct a curve for the dependence of the rate constant k of a simple one-step chemical reaction on the reverse temperature $1/T$.

52. The figure shows the energy plots for two different mechanisms of the same chemical reaction. The activation energy of the catalyst-assisted reaction has a numerical value corresponding to:

(1) A
(2) B
(3) C
(4) D



53. The chemical reaction rate is specified by the equation:

$v = k\,[A]^x\,[B]^y\,[C]^z$

If the concentration of substance A is doubled (the concentrations of substances B and C remaining unchanged), the reaction rate increases by a factor of 8. If the concentration of B increases two-fold (the concentrations of A and C remaining constant), the reaction rate increases two-fold. If the concentration of C increases by a factor of 2 (with unchanged A and B concentrations), the reaction rate increases four-fold. Exponents x, y, and z for the corresponding concentrations of A, B, and C in the equation for the reaction rate have the values:

(1) 1, 0, and 2
(2) 2, 1, and 2
(3) 3, 1, and 2
(4) 4, 1, and 2

54. The equilibrium of the reaction

$Fe_3O_4 + 4CO \rightleftharpoons 3Fe + 4CO_2 - 43.7$ kJ

is shifted to the left if
(1) the temperature is lowered
(2) the temperature is elevated
(3) the pressure is decreased
(4) the pressure is increased

55. Consider the system in equilibrium

$$2CO\ (gas) + O_2\ (gas) \rightleftharpoons 2CO_2\ (gas) + Q$$

Indicate the direction of the equilibrium shift after the following changes occurring in the system:

	Change in the system	*Equilibrium shif*
(1)	Addition of CO_2	...
(2)	Increase in the volume	...
(3)	Increase in the pressure	...
(4)	Removal of CO_2	...
(5)	Temperature elevation	...

56. Which ratio corresponds to the equilibrium constant K_e for the chemical equilibrium described by the reaction equation?

$$2NO + O_2 \rightleftharpoons 2NO_2\ \text{(all gases)}$$

(1) $\dfrac{[NO]\,[O_2]}{[NO_2]}$ (3) $\dfrac{[NO_2]^2}{[NO]^2\,[O_2]}$

(2) $\dfrac{[NO]^2\,[O_2]}{[NO_2]^2}$ (4) $\dfrac{[NO_2]}{[NO]\,[O_2]}$

57. An increased pressure in the system will result in an increased yield of the reaction products for the reaction:

(1) $2H_2O \rightleftharpoons 2H_2 + O_2$ (all gases)
(2) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (all gases)
(3) $CaCO_3$ (solid) $\rightleftharpoons CaO$ (solid) $+ CO_2$ (gas)
(4) $CO + H_2O \rightleftharpoons CO_2 + H_2$ (all gases)

58. Hydrogen reacts with iodine according to the equation .... The equilibrium constant of the reaction is .... Which of the conditions listed below will alter the equilibrium constant?

(1) Introduction of a catalyst into the system
(2) Elevation of the temperature
(3) Increase in the concentrations of the reactants
(4) Increase in the concentrations of the products

59. Ammonium aluminium sulphate reacts with baryta water and involves the following processes:

(1) $SO_4^{2-} + \ldots$
(2) $Al^{3+} + \ldots$
(3) $NH_4^+ + \ldots$
(4) in addition, . . .

60. Each of the reaction equations given below lacks one reactant. Write its formula and the appropriate stoichiometric coefficient:

(1) $FeS + H_2SO_4 \rightarrow FeSO_4 + \ldots$
(2) $4Zn + 10HNO_3$ (sln) $\rightarrow NH_4NO_3 + \ldots + 3H_2O$
(3) $8Al + \ldots \rightarrow 9Fe + 4Al_2O_3$
(4) $\ldots + 2O_2 \rightarrow SiO_2 + 2H_2O$

61. Which reaction practically does not go to completion?

(1) $Na_2SiO_3 + H_2SO_4 \rightarrow \ldots$
(2) $CaO + HCl \rightarrow \ldots$
(3) $NaOH + Al(OH)_3 \rightarrow \ldots$
(4) $CsI + NaCl \rightarrow \ldots$

62. Potassium chromate, iron(II) chloride, and sulphuric acid react to yield the following processes:

(1) $CrO_4^{2-} + \ldots$
(2) $Fe^{2+} + \ldots$
(3) (with high concentrations of Cl^- and H_2SO_4) . . .

63. Metallic copper is known to dissolve in an aqueous solution of iron(III) chloride. The reaction yields:

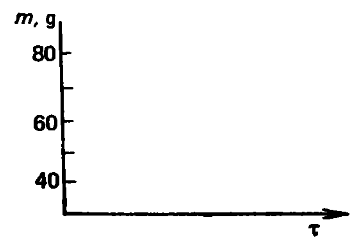
(1) $Cu(OH)_2$ and $Fe(OH)_3$
(2) $CuCl_2$ and Fe
(3) $CuCl_2$ and $FeCl_2$
(4) $CuCl_2$ and H_2

64. Calcined soda reacts with sodium hydrosulphate when H^+ ions are in excess according to the equation ..., and when CO_3^{2-} ions are in excess, according to the equation ....

65. Decomposition of organic substances in the absence of the air yields hydrogen compounds of non-metals. Complete equations for the reactions of oxidation of the hydrogen compounds given below with oxygen. Assume that the non-metal is oxidized to a compound in which it exhibits the highest oxidation state:

(1) $CH_4 + O_2 \rightarrow \ldots$
(2) $H_2S + O_2 \rightarrow \ldots$
(3) $PH_3 + O_2 \rightarrow \ldots$

66. A sample of iron(III) hydroxide weighing 53.5 g was placed in a furnace heated to a temperature higher than the temperature of the hydroxide decomposition. Make a plot for the dependence of the sample mass m on the ignition time τ.



67. The syntheses:

(1) $SO_2 \rightarrow Na_2SO_4$
(2) $O_2 \rightarrow O_3$
(3) $Ba(OH)_2 \rightarrow BaH_2$
(4) $Na_2SO_4 \rightarrow Na_2S_2O_3 \cdot 5H_2O$

involve oxidation-reduction processes except the synthesis .. ..

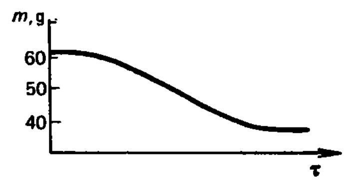
68. At the close of the nineteenth century, the British chemist and industrialist Ludwig Mond discovered that nickel powder reacts with carbon(II) oxide to yield a mononuclear complex, nickel tetracarbonyl $Ni(CO)_4$, which is a colourless highly volatile liquid. Which metal forms compounds with M-M bonds (metal-metal bonds), rather than mononuclear carbonyl com-

plexes of $M(CO)_x$ type (where M stands for metal)?

(1) Ni (3) Cr
(2) Mn (4) Fe

69. The ozone cycle in the atmosphere involves nitrogen oxides as important components, whose percentage is rather low. Ozone reacts with NO to form NO_2 and O_2; NO_2, in turn, reacts with nascent oxygen present in stratosphere to yield NO and O_2. The net reaction of ozone interaction is ....

70. A sample of $KClO_3$ weighing 61.25 g was subjected to decomposition and suitable plots were made from the experimental data (dependence of the sample mass m on time τ), see the figure below. Write equations for the reactions corresponding to the experimental conditions given below. Which condition was employed for making the plot?



(1) At a temperature of about 400 °C
(2) In the presence of MnO_2, at a temperature of about 200 °C

Chapter **2**

Do You Know the Chemistry of the Elements?

2.1 Chemistry of the Halogen Family

...Moissan set himself a very important and complicated task—that of obtaining free fluorine. The problem was tackled by many chemists, beginning with H. Devy. ...On June 26, 1886, Moissan, after getting over all kinds of difficulties, was the first to produce fluorine by electrolysis of hydrofluoric acid using a device constructed of platinum tubes... .

Zh. VKhO im. D.I. Mendeleeva

1. Simple substances change their colour gradually with increasing atomic number of the halogens they consist of. Complete the table below for halogens under ordinary conditions:

	Element	*State of aggregation*	*Colour*
(1)	Fluorine	...	...
(2)	Chlorine	...	...
(3)	Bromine	...	...
(4)	Iodine	...	...

2. Melting and boiling points for halogens—simple substances—in a subgroup of the periodic system, with an increasing atomic number of an element

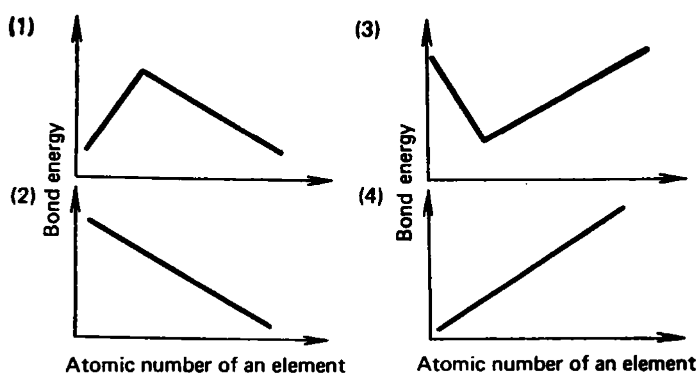
(1) decrease
(2) increase
(3) remain unchanged
(4) decrease and then increase

3. The electronic formula of the outermost energy level, which is the same for all halogen atoms, can be represented as ..., where n is the number of the energy level.

4. Chlorine was the first halogen that was obtained in a free state. In 1774, the Swedish chemist Karl Scheele produced it by heating pyrolusite with hydrochloric acid according to the reaction ....
5. Halogens exhibit the following common properties:

   (1) in the gaseous state they exist as diatomic molecules
   (2) with alkali metals, they are capable of forming compounds of MHal type, which are ionic solids
   (3) they form covalent bonds when combine with hydrogen and carbon
   (4) they exhibit only oxidative properties

   Statement ... is wrong.
6. Under ordinary conditions, chlorine is a gas coloured ..., of a density of ... g/litre. It can be liquefied at ... °C.
7. The bond energy in elemental halogens will change with the atomic number of an element approximately in this way:



8. One cannot say that fluorine is

   (1) the most active element
   (2) the most electronegative element
   (3) the most aggressive element
   (4) the lightest element

9. Oxidative properties are most pronounced in

(1) fluorine (3) bromine
(2) chlorine (4) iodine

10. Reductive properties are most pronounced in

(1) fluorine (3) bromine
(2) chlorine (4) iodine

11. The high chemical activity of fluorine can be attributed to the fact that

(1) it has the highest electronegativity value (4.0)
(2) its molecule has the lowest dissociation energy, and the chemical bond in the majority of fluorine compounds is extremely strong
(3) the outer electron level lacks only one electron for its complete accommodation
(4) its molecule has a relatively small mass rendering it mobile

12. In contrast to the other halogens, fluorine vigorously reacts with

(1) Na (3) H_2
(2) P (4) SiO_2

13. Fluorine can react with noble gases. Which of these noble gases

(1) Ne (3) Kr
(2) Ar (4) Xe

burns brightly in fluorine to yield a product of the AB_4 type according to the reaction equation ... ?

14. Fluorine is a stronger oxidizing agent than oxygen. Therefore it reacts with water mainly with the formation of a simple substance according to the equation ... .

15. One volume of gaseous chlorine reacts with three volumes of gaseous fluorine to yield two volumes of the gaseous product ... according to the reaction equation ... (the volumes of the gases have been measured at the same temperature and pressure).

16. Which statement concerning chlorine atoms is wrong?

(1) The nuclei of chlorine atoms differ from the nuclei of all the other elements by the number of protons
(2) The neutral chlorine atoms differ from the neutral atoms of all the other elements by the number of electrons
(3) Chlorine atoms are characterized by a higher ratio of the number of neutrons to the number of protons than the atoms of the other elements
(4) The chemical behaviour of chlorine atoms varies from that of the neutral atoms of the other elements

17. Free chlorine can evolve in the reaction:

(1) $HCl + Mg \rightarrow \ldots$
(2) $HCl + MgO \rightarrow \ldots$
(3) $HCl + Br_2 \rightarrow \ldots$
(4) $HCl + F_2 \rightarrow \ldots$

18. Fabric and paper are decolourized by bleaching powder, which can be produced by reacting chlorine with

(1) H_2O (3) $Ca(OH)_2$
(2) KOH (4) $Mg(OH)_2$

19. Heats of formation of higher sodium chlorides and antimony are nearly equal. Which process will release more heat?

(1) Combustion of 5 g of sodium in chlorine
(2) Combustion of 5 g of antimony in chlorine

20. A sample of gaseous chlorine of the mass 0.01 g is placed in a sealed 10 cm^3 glass ampoule. It is heated from 0 to 273 °C. The initial chlorine pressure at 0 °C is ... kPa.

21. The chlorine pressure at 273 °C (see Problem 20) equals ... kPa.

22. Chlorine vigorously reacts with hydrogen once exposed to ultraviolet light in the reaction $H_2 + Cl_2 \xrightarrow{h\nu} 2HCl$. The mechanism of this reaction can be described by these reactions:

(1) $H_2 + Cl_2 \xrightarrow{h\nu} HCl + HCl$

(2) $H_2 \xrightarrow{h\nu} H^+ + H^-$

$Cl_2 \xrightarrow{h\nu} Cl^+ + Cl^-$

$H^+ + Cl^- \rightarrow HCl$

$H^- - \bar{e} \rightarrow H^\cdot$

$Cl^+ + \bar{e} \rightarrow Cl^\cdot$

$H^\cdot + Cl^\cdot \rightarrow HCl$

(3) $Cl_2 \xrightarrow{h\nu} Cl^\cdot + Cl^\cdot$

$H_2 + Cl^\cdot \rightarrow HCl + H^\cdot$

$H^\cdot + Cl_2 \rightarrow HCl + Cl^\cdot$

$H^\cdot + Cl^\cdot \rightarrow HCl$ etc.

(4) $H_2 + Cl_2 \xrightarrow{h\nu} HCl_2^\cdot + H^\cdot$

$HCl_2^\cdot \rightarrow Cl^\cdot + HCl$

$H^\cdot + Cl^\cdot \rightarrow HCl$

23. How many moles (at a maximum) of NaCl can be produced from one mole of sodium and two moles of chlorine by the reaction

$2Na + Cl_2 \rightarrow 2NaCl$?

(1) 1 (3) 3
(2) 2 (4) 4

24. Which halide shows the highest melting point?

(1) NaF (3) NaBr
(2) NaCl (4) NaI

25. Mixed are two solutions containing equal masses of sodium chloride and silver nitrate (20 g). The precipitate mass (g) is equal to

(1) 16.8 (3) 48.8
(2) 33.6 (4) 97.7

26. Consider the series of chlorides with higher oxidation states of the third period elements of the periodic table. With increasing atomic number of elements, the compounds exhibit:

(1) an increase in acidic properties and a decrease in basic properties
(2) an increase in basic properties and a decrease in acidic properties
(3) acidic properties remain unchanged
(4) basic properties remain unchanged

27. Acidic chlorides, e.g. $SiCl_4$, are practically completely and irreversibly hydrolyzed to yield acids according to the reaction equation ... .
28. The heat of reactions of combination of halides with hydrogen in the series from fluorine to iodine

(1) increases
(2) decreases
(3) increases and then decreases
(4) remains unchanged

29. Chlorine is prepared in the laboratory from ... treating it with ... .
30. If you use one of the substances suggested in Problem 29, the schematic of a setup that can be employed for the preparation of chlorine in the laboratory is this ... .
31. Which of the following techniques for chlorine production is commonly not used in the laboratory?

(1) Oxidation of concentrated HCl with manganese dioxide
(2) Oxidation of concentrated HCl with potassium permanganate
(3) Oxidation of concentrated HCl with potassium dichromate
(4) Catalytic oxidation of gaseous hydrogen chloride with oxygen of the air

32. Which gas is mainly formed from the reaction between Berthollet's salt and concentrated hydrochloric acid?

(1) H_2 (3) HCl
(2) Cl_2 (4) Cl_2O

33. Preparation of gaseous hydrogen chloride in the laboratory by reacting sulphuric acid with sodium chloride requires:

(1) solid sodium chloride and dilute sulphuric acid
(2) solid sodium chloride and concentrated sulphuric acid
(3) dilute solution of sodium chloride and dilute sulphuric acid
(4) dilute solution of sodium chloride and concentrated sulphuric acid

34. Which of the following should not be used for desiccation of hydrogen chloride?

(1) Soda lime
(2) Phosphorus(V) oxide
(3) Concentrated sulphuric acid
(4) Silica gel

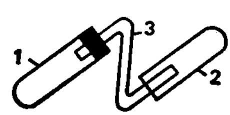
35. Halogen oxyacids exhibiting an oxidation state of +1 are characterized by a decrease in the relative oxidative activity in the sequence:

(1) HOI—HOBr—HOCl
(2) HOCl—HOBr—HOI
(3) HOBr—HOI—HOCl
(4) HOBr—HOCl—HOI

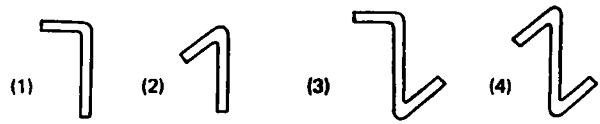
36. A vessel was divided into two equal parts with a partition. Chlorine under a pressure of 400 kPa was placed in one part and hydrogen under a pressure of 200 kPa in the other. If we remove the partition, the overall pressure (kPa) in the vessel will become

(1) 200 (3) 400
(2) 300 (4) 600

37. An experimental setup that can be used for the preparation of a number of substances can easily be arranged using two test tubes (*1* and *2*) and a gas-discharge tube (*3*)—see the figure. For example, you are to obtain hydrogen chloride in the labor-



atory by the displacement of the air. Here you will use the following gas-discharge tube:



38. Hypochlorous acid has the formula

(1) $HClO$ (3) $HClO_3$
(2) $HClO_2$ (4) $HClO_4$

39. The mass fraction of chlorine is the highest in

(1) $KClO$ (3) $KClO_3$
(2) $KClO_2$ (4) $KClO_4$

40. Can we consider the evolution of hydrogen in the reaction between zinc and an aqueous solution of hydrogen chloride to be a strict proof of the fact that hydrogen is a constituent part of HCl molecule?

(1) No, we can't, because zinc does not react with hydrochloric acid
(2) No, we can't, since water, which is a constituent part of the solution, contains hydrogen
(3) No, we can't, because zinc chloride is also obtained, in addition to hydrogen
(4) Yes, we can, since zinc reduces hydrogen ions of the hydrochloric acid

41. Which of the reactions whose skeleton equations are given below shows an alteration in the chlorine oxidation state from +1 to 0?

(1) $MnO_2 + HCl \rightarrow \ldots$
(2) $KClO_3 \xrightarrow{T,\ MnO_2} \ldots$
(3) $NaClO + HCl \rightarrow \ldots$
(4) $KClO_3 \xrightarrow{T} KClO_4 + KCl$

42. A hydrogen-chlorine mixture placed in a closed vessel at a constant temperature was irradiated with scat-

tered light. After a time, the chlorine percentage decreased by 20% as compared with the initial concentration, and the volume percent of the components at this instant were: 60% for chlorine, 10% for hydrogen, and 30% for hydrochloride. The initial mixture contained ... % chlorine and ... % hydrogen.

43. Complete equations for the reactions between halides and sulphuric acid:

(1) CaF_2 (solid) + H_2SO_4 (conc.) → . . .
(2) NaCl (solid) + H_2SO_4 (liquid) → . . .
(3) NaBr (solid) + H_2SO_4 (liquid) → . . .
(4) NaI (solid) + H_2SO_4 (liquid) → . . .

44. Hydrochloric acid exhibits oxidative properties in the reaction ... .

45. 13 g of zinc was placed in a solution obtained by passing 11.2 litres of hydrogen chloride gas through 100 cm³ of water. The volume (in litres) of the resulting gas (at STP) was:

(1) 22.40 (3) 5.60
(2) 11.20 (4) 4.48

46. The stability of chlorine compounds increases in the sequence $H\overset{+1}{Cl}O$—$H\overset{+5}{Cl}O_3$—$H\overset{+7}{Cl}O_4$. The strongest oxidant is ... .

47. Potassium chlorate is prepared in the laboratory in the reaction ... which occurs on ... .

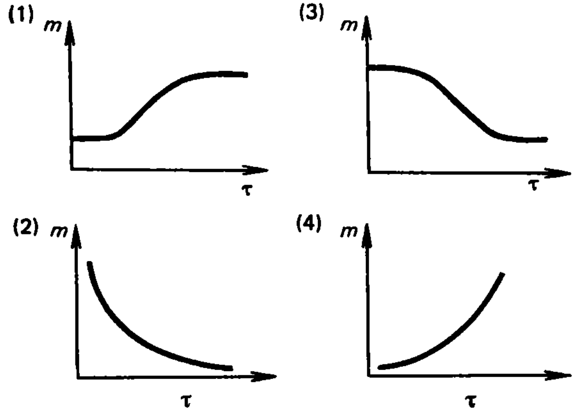
48. If 2.45 g of Berthollet's salt is decomposed completely, the resulting gas volume measured at STP will be equal to ... litre.

49. Write equations for the reactions that describe the four transformations of substances according to the scheme:

$$HCl \underset{(2)...}{\overset{(1)...}{\rightleftharpoons}} Cl_2 \underset{(4)...}{\overset{(3)...}{\rightleftharpoons}} KClO_3$$

50. Berthollet's salt is strongly heated in an open quartz tube until its complete decomposition. Which curve

is valid for describing the dependence of mass m of the substance in the reaction tube on time τ?



51. Methane reacts with chlorine in the light as follows:

$$CH_4 + Cl_2 \xrightarrow{h\nu} CH_3Cl + HCl$$

The mechanism of this process is similar to that of the reaction between chlorine and hydrogen in the light. It involves chlorine atoms and methyl radicals $\cdot CH_3$. Which of the steps given below fails to describe chain breaking?

(1) $\cdot CH_3 + \cdot Cl \rightarrow CH_3Cl$
(2) $\cdot CH_3 + HCl \rightarrow CH_4 + \cdot Cl$
(3) $\cdot CH_3 + \cdot CH_3 \rightarrow C_2H_6$
(4) $\cdot Cl + \cdot Cl \rightarrow Cl_2$

52. Oxidation of hydrogen bromide gas in the temperature range from 400 to 600 °C proceeds according to the equation

$$4HBr + O_2 = 2H_2O + 2Br_2 \text{ (all gases)}$$

Its mechanism can be described as follows:

(1) $HBr + O_2 \xrightarrow{k_1} HOOBr$ (slow step)

(2) $HOOBr + HBr \xrightarrow{k_2} 2HOBr$ (fast step)

(3) $HOBr + HBr \xrightarrow{k_3} H_2O + Br_2$ (fast step)

The kinetic equation for the rate of the oxidation of hydrogen bromide is . . . .

53. One mole of substance X reacts with one mole of water to yield one mole of oxygen and two moles of hydrogen fluoride:

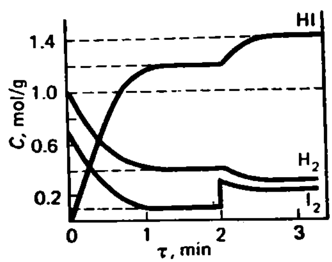
$$X + H_2O = O_2 + 2HF$$

Substance X has the formula

(1) F_2 (3) F_2O_2
(2) OF_2 (4) HOF

54. The reaction between hydrogen and iodine gases is described by the equation

$$H_2 + I_2 + Q \rightleftarrows 2HI$$
(all gases)

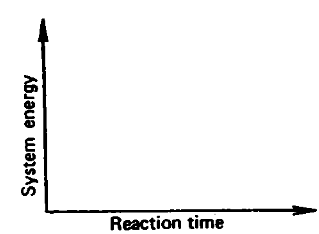


The figure shows concentrations C of reactants and products as functions of time τ.

What change in the system can be observed two minutes after the onset of the reaction?

(1) Pressure has increased
(2) Temperature has increased
(3) Hydrogen H_2 (gas) has been added to the system
(4) Iodine I_2 (gas) has been added to the system

55. Interaction of one mole of gaseous hydrogen with one mole of crystalline iodine requires 50 kJ of heat. Plot the dependence of the energy of the closed system on the time of the H_2-I_2 interaction for the following two cases:



(1) without a catalyst
(2) in the presence of a catalyst

56. Which of the reactions whose equations are given below cannot occur?

(1) $5Cl_2 + Br_2 + 6H_2O = 10HCl + 2HBrO_3$
(2) $5I_2 + Br_2 + 6H_2O = 10HI + 2HBrO_3$
(3) $5Cl_2 + I_2 + 6H_2O = 10HCl + 2HIO_3$

57. Which reaction cannot go?

(1) $2H_2O + 2F_2 = 4HF + O_2$
(2) $2NaBr + Cl_2 = 2NaCl + Br_2$
(3) $2KI + Cl_2 = 2KCl + I_2$
(4) $2KBr + I_2 = 2KI + Br_2$

58. Bromic acid has the formula $HBrO_3$ and dysprosium oxide, Dy_2O_3. Dysprosium bromate has the following formula:

(1) Dy_2BrO_3 (3) $Dy(BrO_3)_3$
(2) Dy_3BrO_3 (4) $Dy_2(BrO_3)_3$

59. Iodine solubility in pure water is low. It is significantly higher in solutions containing iodide ions. The dependence of the overall solubility of iodine on the concentration of iodide ions is studied to determine the corresponding equilibrium constants. Write the expressions for equilibrium constants K.

	Reaction	*Equilibrium constant K*
(1)	I_2 (solid) $\rightleftarrows$ I_2 (sln)	...
(2)	I_2 (solid) + I^- (sln) $\rightleftarrows$ I_3^-(sln)	...
(3)	I_2 (sln) + I^- (sln) $\rightleftarrows$ I_3^- (sln)	...

The expression for the equilibrium constant K_3 can also be presented through the equilibrium constants of the first two processes:

(a) K_1/K_2
(b) K_2/K_1
(c) K_1/K_2

60. Periodic acid can be produced by oxidizing iodine with concentrated nitric acid according to the reaction . . . .

2.2 Sixth Group Elements

"The two most important members of the group are oxygen and sulphur, and we deal mainly with them..."

P.W. Atkins

1. The electronic configuration of atoms of Group VIA elements of the periodic system can be presented as the common formula . . ., where n is the number of energy level.
2. Some properties of atoms of VIA Group elements such as atomic and ionic (E^{2-}) radii in the series O—S—Se—Te regularly

   (1) decrease
   (2) increase
   (3) remain unchanged
   (4) decrease and then increase

   and some, such as electronegativity and the first ionization potential (ionization energy)

   (1) decrease
   (2) increase
   (3) remain unchanged
   (4) decrease and then increase

3. Write electronic configurations for the ground states of the atoms:

   $^{18}_{8}O$ . . . $^{16}_{8}O$ . . .

4. Oxygen exhibits a positive oxidation state in the compound:

   (1) Na_2O (3) H_2O_2
   (2) KNO_3 (4) OF_2

5. The mass (in g) of 50.0 litres of oxygen at STP equals

   (1) 32 (3) 100
   (2) 71.4 (4) 143

6. A sample of air contains 210 cm^3 of oxygen, 780 cm^3 of nitrogen, and 10 cm^3 of other gases at a pressure of

98.66 kPa. The partial pressure (in kPa) of the oxygen in the air sample is equal to

(1) 10.40 (3) 41.33
(2) 20.72 (4) 77.33

7. How many moles of oxygen are formed from three moles of potassium chlorate after its complete thermal decomposition?

(1) 6.0 (3) 3.0
(2) 9.0 (4) 4.5

8. The total pressure of the mixture of two moles of oxygen and three moles of hydrogen is equal to 800 kPa. The partial pressure (in kPa) of oxygen in the mixture equals

(1) 320 (3) 480
(2) 400 (4) 533

9. Oxygen evolves during thermal decomposition of a number of compounds. Equal samples (by mass, e.g. 10 g each) of mercury(II) oxide, potassium chlorate, potassium permanganate, and potassium nitrate have decomposed. Which sample releases the greatest number of moles of oxygen?

(1) HgO (3) $KMnO_4$
(2) $KClO_3$ (4) KNO_3

10. Alkaline metals are heated in dry air to yield oxygen compounds. Formation of which compound is unlikely under these conditions?

(1) Li_2O (3) Na_2O_2
(2) Na_2O (4) KO_2

11. At STP, 1.5 moles of oxygen gas occupy a volume of (in litres):

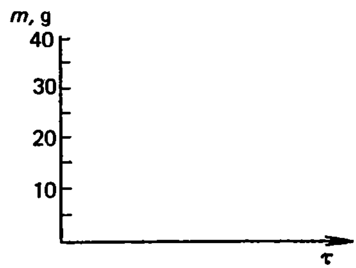
(1) 11.2 (3) 22.4
(2) 16.0 (4) 33.6

12. Sixteen grams of oxygen can yield (as a maximum) this mass (in g) of ozone:

(1) 12.0 (3) 24.0
(2) 16.0 (4) 32.0

13. Ozone is passed through a solution of potassium iodide to yield the redox reaction ... .

14. A sample of potassium permanganate weighing 30 g was placed in a furnace heated to the temperature of permanganate decomposition. Plot a graph for the dependence of the sample mass m on the time of calcination τ.



15. Liquid oxygen can be attracted by a magnet—it exhibits paramagnetic properties. This phenomenon can be attributed to the fact that oxygen molecule has

(1) unpaired electrons
(2) paired electrons
(3) oxygen atoms, each surrounded by 8 electrons
(4) oxygen atoms whose p orbital accommodates a single unpaired electron

16. It is known that 1 g of ice melts at 0 °C with the absorption of 333.5 J of heat. Heat of melting of 1 mole of ice at this temperature is ... J/mole.

17. Eight grams of hydrogen and 8 g of oxygen were mixed and then ignited. The mass (in g) of the resulting water is

(1) 8 (3) 16
(2) 9 (4) 18

18. Which gas of those listed below cannot burn in oxygen?

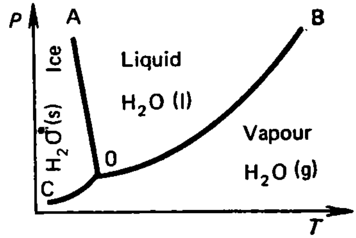
(1) Carbon(II) oxide (3) Hydrogen
(2) Methane (4) Carbon(IV) oxide

19. Which mass (in g) of 20% hydrochloric acid (as a minimum) should be taken to dissolve 11 g of iron(II) sulphide completely?

(1) 2.28 (3) 9.12
(2) 4.56 (4) 45.60

20. Oxygen is formed during decomposition of
(1) $CaCO_3$ (3) H_2SO_4
(2) HgO (4) $(CuOH)_2CO_3$

21. Examine closely the phase diagram for water given, i.e. the conditions under which ice converts to liquid water and vapour depending on pressure P and temperature T.



When you are skating at temperatures close to zero, the ice melts under your skates and sliding is actually effected in a thin layer of water. This occurs because
(1) the pressure and the vaporization point of H_2O (liquid) increase along the curve OB
(2) the pressure increases while the melting point of H_2O (solid) decreases along the curve OA
(3) the pressure and the melting point of H_2O (solid) decrease along the curve OA
(4) the pressure decreases and the equilibrium between the ice, liquid, and vapour is reached (point O)

22. An increase in pressure ... (raises, lowers?) the melting point of ice.

23. The oxides of the 3rd period elements—Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, SO_3, and Cl_2O_7—exhibit from left to right across the period
(1) an increase in the basic function
(2) an increase in the acidic function
(3) an increase in the amphoteric function
(4) cannot be judged about the change in their chemical nature

Here the effective charges δ on the oxygen atom
(a) increase
(b) decrease
(c) increase and then decrease
(d) practically remain unchanged

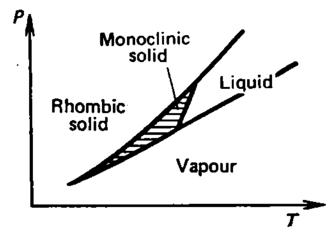
24. Find the minimal mass (in g) of oxygen that is needed for complete combustion of 32 g of sulphur:

(1) 16 (3) 28
(2) 22 (4) 32

25. Which of the compounds listed below is characterized by the maximum mass percent of sulphur?

(1) Na_2SO_3 (3) $Na_2S_4O_6$
(2) $Na_2S_2O_3$ (4) $Na_2S_2O_8$

26. Consider the phase diagram for sulphur in the figure, i.e. the conditions under which solid sulphur converts to liquid and vapour sulphur depending on the pressure *P* and temperature *T*.



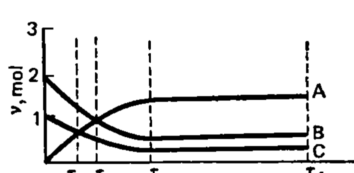
Tell how the melting point of sulphur will change when the pressure is increased:

(1) it will decrease
(2) it will rise
(3) it will remain unchanged

27. A sample of zinc and a two-fold mass of sulphur were heated with no air admitted to the crucible. Which reaction products can be found in the crucible?

(1) Pure zinc sulphide
(2) A mixture of zinc sulphide and sulphur
(3) A mixture of zinc and zinc sulphide
(4) A zinc-sulphur mixture

28. The figure shows a change in the number of moles (ν, mole) of the reactants and products in the reaction for production of sulphur(VI) oxide from sulphur(IV) oxide as the reaction was reaching an equilibrium.



Substances A, B, and C are, respectively:

(1) SO_3, SO_2, and O_2 (3) SO_3, O_2, and SO_2
(2) SO_2, O_2, and SO_3 (4) O_2, SO_2, and SO_3

29. In the figure for Problem 28, the equilibrium state is reached at

(1) τ_1 (3) τ_3
(2) τ_2 (4) τ_4

30. Formation of sulphur(VI) oxide from oxidation of sulphur(IV) oxide is hindered by ... (raising, lowering?) the temperature and ... (increasing, decreasing?) the pressure.

31. A mixture of sulphur(IV) oxide and air is passed through a glass tube. The product, sulphur(VI) oxide, appears in the receiver:

(1) at room temperature
(2) on heating the mixture to 500 °C
(3) when iron(III) oxide is placed in the tube and the mixture heated to 500 °C
(4) at room temperature and introduction of iron(III) oxide into the tube

32. A black precipitate is deposited when the following gas is passed through a solution of lead salt:

(1) CO_2 (3) H_2S
(2) N_2 (4) O_2

33. Given

S (solid) + O_2 (gas) $\rightarrow$ SO_2 (gas) + 296.9 kJ
SO_2 (gas) + 1/2O_2 (gas) $\rightarrow$ SO_3 (gas) + 101.3 kJ

The heat of formation of SO_3 (gas) (in kJ) according to the equation

S (solid) + 3/2O_2 (gas) = SO_3 (gas)

equals

(1) 195.6 (3) 796.4
(2) 398.2 (4) 499.5

34. Heats of combustion of monoclinic sulphur S (m) and rhombic sulphur S (r) are, respectively, +296.83

and +297.21 kJ/mole. Heat of conversion of 1 mole of monoclinic sulphur to rhombic sulphur is ... kJ.

35. Calculate the number of moles of FeS_2 that is required to produce 64 g of SO_2 by the reaction

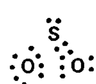
$$4FeS_2 + 11O_2 = 2Fe_2O_3 + 8SO_2$$

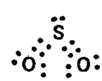
(1) 0.4 (3) 3.2
(2) 0.5 (4) 6.0

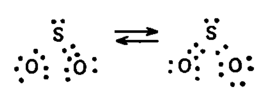
36. What is the volume (in litres) of 8.0 g of sulphur(IV) oxide at STP?

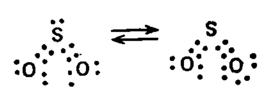
(1) 2.8 (3) 11.2
(2) 5.6 (4) 22.4

37. Which scheme is the most correct representation of the electron dot symbol for the formation of a chemical bond in the sulphur(IV) oxide molecule?

(1)


(3)


(2)


(4)


38. A bundle of copper wires burns in sulphur vapour yielding ... .

39. J. Priestley prepared sulphur dioxide by heating mercury with concentrated sulphuric acid:

Hg (liquid) + $2H_2SO_4$ (liquid) = $HgSO_4$ (solid) + SO_2 (gas) + $2H_2O$ (gas)

At present, in the laboratory, SO_2 can be obtained using ... and ... as reactants. Preparation of SO_2 by reacting ... with ... is a method differing in essence from the former.

40. In the sequence $H_2O—H_2S—H_2Se—H_2Te$ the strength of the acids

(1) decreases
(2) increases

(3) remains unchanged
(4) decreases and then increases

41. About 2.3 litres of hydrogen sulphide dissolves in 1 litre of water at STP. The mass percent of hydrogen sulphide in the solution obtained is:

(1) 0.23 (3) 2.3
(2) 0.34 (4) 3.4

42. Hydrogen sulphide is passed through an iron(III) chloride solution yielding the reaction ... .

43. Sodium hydroxide (concentrated solution) was added to sulphur (powder) in a crucible. Then the mixture was boiled for some time. A piece of paper wetted with $Pb(NO_3)_2$ solution turned black when dipped into the mixture. This indicates that the solution contains sulphide ions formed in the reaction ... .

44. Concentrated sulphuric acid taken in excess reacts with copper on heating to yield:

(1) $CuSO_4 + H_2$ (3) $CuSO_4 + H_2O + SO_2$
(2) $CuO + H_2SO_3$ (4) $CuO + H_2S$

45. In order to dilute sulphuric acid one must add the acid to water. It is dangerous to dilute concentrated H_2SO_4 by adding water to it because

(1) a fire hazard arises
(2) decomposition of water may occur
(3) a noxious gas may evolve
(4) splashing of the solution may take place due to heat release

46. Concentrated sulphuric acid is commonly reduced by zinc to sulphur(IV) oxide. The mass of sulphur(IV) oxide (in g) formed after complete interaction between zinc and a concentrated sulphuric acid solution containing 245 g of the acid is

(1) 64.0 (3) 128
(2) 80.0 (4) 160

47. Write equations for the reactions following the pathways given below for obtaining sulphate soluble in water.

Pathway	Reaction equation
(1) Interaction of metals with H_2SO_4 solution	...
(2) Decomposition of salts of volatile acids by sulphuric acid	...
(3) Oxidation of sulphites or sulphides	...

48. Hydrogen sulphide can be synthesized from simple substances using the apparatus ... .

49. Hydrogen sulphide and neon are at the same temperature and pressure. The volume (in litres) of hydrogen sulphide containing the same number of molecules as 10.0 litres of neon do is equal to:

(1) 3.33 (3) 22.4
(2) 10.0 (4) 30.0

50. A 1.5-litre closed vessel contained a mixture of hydrogen sulphide and excess oxygen at STP. The mixture was ignited. The products of the reaction were dissolved in 49.2 cm^3 of water and a 1.64% acid solution was obtained. The initial mixture contained:

(1) 0.34 litre H_2S and 1.16 litres O_2
(2) 0.60 litre H_2S and 0.90 litre O_2
(3) 0.44 litre H_2S and 1.06 litres O_2
(4) 0.22 litre H_2S and 1.28 litres O_2

51. Heats of formation of some complex substances from simple substances are given below (heat of formation of a simple substance equals zero). The heat (kJ) of combustion of 1 mole of hydrogen sulphide is

		Gas	*Heat of formation*, kJ/mole
(1)	+1124	H_2S	+21
(2)	−1124	O_2	0
(3)	+562	H_2O	+286
(4)	−562	SO_2	+297

52. Choose that rhs of the equation which corresponds to the equation of the reaction between lead(II) nitrate solution and ammonium sulphide:

(1) $2NH_4NO_3$(solid) + Pb^{2+} + S^{2-}
(2) $Pb(NO_3)_2$ (solid) + $2NH_4^+$ + S^{2-}
(3) $(NH_4)_2S$ (solid) + Pb^{2+} + $2NO_3^-$
(4) PbS (solid) + $2NH_4^+$ + $2NO_3^-$

Complete the ionic equation for this reaction ... .

53. Copper(II) sulphide reacts with hot nitric acid yielding nitrogen(II) oxide and free sulphur. The reaction reads: ... .

54. A mixture of 3.0 g sulphur and 12.7 g copper was placed in a quartz tube. The tube was sealed under vacuum and then heated to the melting point of the mixture. The cooled tube contained

(1) copper(I) sulphide
(2) a mixture of copper(I) sulphide with sulphur
(3) a mixture of copper(I) sulphide with copper
(4) a sulphur-copper mixture

55. Sulphur(IV) oxide solution can be used as reductant. Write equations for the transformations listed below.

Reduction of	*Reaction equation*
(1) $KMnO_4$ solution to $MnSO_4$	...
(2) acidic solution of $K_2Cr_2O_7$ to Cr^{3+}	...
(3) mercury(I) nitrate solution to metallic mercury	

56. The products of the reaction between sulphur and iron on combustion were dissolved in hydrochloric acid. The dissolution was complete, and the volume of the gases evolved was 4.48 litres (at STP). The gaseous products were passed through lead(II) nitrate solution to yield 23.9 g of precipitate. The initial composition of the mixture was:

(1) 11.2 g Fe, 3.2 g S
(2) 5.6 g Fe, 3.2 g S
(3) 2.8 g Fe, 1.6 g S
(4) 11.2 g Fe, 6.4 g S

57. Hydrogen sulphide reacts with a solution of

(1) Na_2SO_4
(2) $CuSO_4$
(3) $FeSO_4$
(4) $CdSO_4$

to yield a yellow precipitate.

58. To solutions of salts containing the ions:

(1) K^+ (3) Pb^{2+}
(2) Bi^{3+} (4) Zn^{2+}

sodium sulphide solution was added. Metal sulphides were precipitated in all the cases except ... .

59. H_2S was passed through bromine water, which was decolorized as a result. The process can be described by the reaction ... .

60. The sulphides of the *s* elements of Group I of the periodic table are readily soluble in water. Their solutions are:

(1) weakly acidic (3) basic
(2) strongly acidic (4) neutral

61. Na_2SO_3 solution has been added to an acidified pink solution of potassium permanganate. One can observe:

(1) turbidity resulting from the precipitation of free sulphur
(2) decoloration due to Mn^{2+} formation
(3) evolution of SO_2 (bubbles)
(4) dark green coloration as a result of MnO_4^{2-} production

62. The most stable molecule of free sulphur is

(1) S_2 (3) S_6
(2) S_4 (4) S_8

63. Hydrofluoric acid can be formed in the reaction between water and

(1) SO_2 (3) SF_4
(2) SO_3 (4) $SOCl_2$

64. SO_2 reacts with Cl_2 in the sunlight to yield

(1) SO_3 (3) $SOCl_2$
(2) SO_2Cl_2 (4) S

65. Strontium sulphide can be represented by the chemical formula:

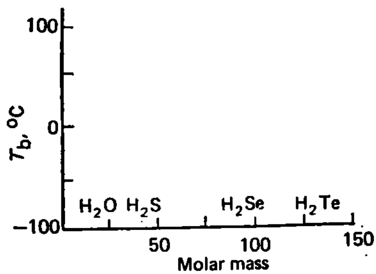
(1) SrS (3) SrS_2
(2) Sr_2S (4) SrS_3

66. Zinc (10 g) and sulphur (10 g) are heated to yield zinc(II) sulphide, whose mass (in g) is:

(1) 10.0 (3) 20.0
(2) 14.9 (4) 88.0

67. The non-metallic properties of the elements in the sequence Se—Te—Po ... (increase, weaken?).

68. If the boiling point of water under atmospheric pressure is 100 °C and that of hydrogen telluride, —2 °C, plot an approximate curve for the variation of the boiling points T_b of the hydrides of VIA Group elements: H_2O, H_2S, H_2Se, and H_2Te.

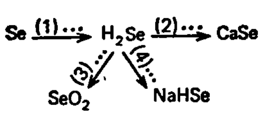


69. Sodium selenite reacts with chlorine in the basic solution to yield the oxidation product ... and the reduction product ... .

70. Rubidium (atomic number 37) is the IA Group element, and tellurium (atomic number 52) is the VIA Group element. The ionic compound rubidium telluride has the formula:

(1) Rb_2Te (3) Rb_3Te_2
(2) $RbTe_2$ (4) Rb_2Te_3

71. Write equations for the reactions resulting in the following conversions:



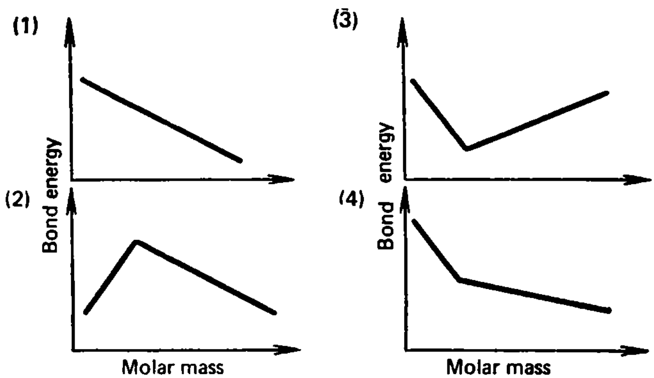
72. Sodium thiosulphate has the formula ... . The salt can be obtained in the reaction ... .

73. Sodium thiosulphate is widely used in photography as a fixative. The process is based on the reaction between thiosulphate and silver chloride ... .

74. A sample of iron(II) sulphide (technical grade) weighing 5 g and containing 5% of metallic iron reacts with hydrochloric acid. The volume of gaseous products evolved during the reaction and reduced to STP equals:

(1) 1.27 litres H_2S
(2) 1.21 litres H_2S
(3) 0.1 litre H_2 and 1.21 litres H_2S
(4) 0.15 litre H_2 and 1.21 litres H_2S

75. The stability of the compounds in the sequence $H_2O—H_2S—H_2Se—H_2Te$ varies in the way shown in the plot:



76. The solubility of sulphates in the series $CaSO_4—SrSO_4—BaSO_4$

(1) increases
(2) decreases
(3) remains unchanged
(4) increases and then decreases

77. The strength of the acids in the sequence $H_2SO_3—H_2SeO_3—H_2TeO_3$

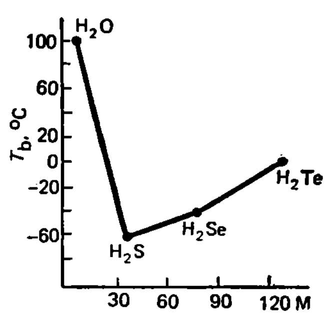
(1) increases
(2) decreases
(3) remains unchanged
(4) increases and then decreases

78. Selenic acid H_2SeO_4 is
(1) a weak oxidant
(2) a weak reductant
(3) a strong oxidant
(4) a strong reductant

79. The formula of calcium selenite is ..., and that of potassium tellurite ... .

80. The figure below shows the boiling points of four compounds. The boiling point of water differs appreciably from the boiling points of the other hydrogen compounds because of

(1) the covalent bond between atoms in the water molecule
(2) the ionic bond between atoms in the water molecule
(3) the hydrogen bond between water molecules
(4) van der Waals attractive forces between water molecules



81. Calcination of 48.5 g of the sulphide of a metal exhibiting the +2 oxidation state yielded a gas that could decolorize a solution containing 127 g of iodine. Name the metal:

(1) Fe (3) Zn
(2) Cu (4) Cd

2.3 Journey in the Fifth Group

"Nitrogen ... is alpha and omega, the start and the end, the first and the last... This enigmatic synthetic word means the 'beginning and the end of the beginning' "

E.D. Terletsky

1. The electronic configuration of the outermost energy level of the atoms of the VA Group elements of the periodic table can be represented as the general formula ..., where n is the number of the energy level.
2. The atoms of which of the VA Group elements can be represented by the electronic configurations given in the table below?

	Electronic configuration	*Element symbol*
(1)	$[Xe]4f^{14}5d^{10}6s^2p^3$	...
(2)	$[Ar]3d^{10}4s^2p^3$	...
(3)	$[He]2s^2p^3$	...
(4)	$[Kr]4d^{10}5s^2p^3$	...
(5)	$[Ne]3s^2p^3$	...

3. With increasing atomic number of elements, the acidic properties of the oxides N_2O_3—P_2O_3—As_2O_3—Sb_2O_3—Bi_2O_3

   (1) increase
   (2) weaken
   (3) remain unchanged
   (4) increase and then weaken

4. The basic properties of the oxides of the VA Group elements of the E_2O_5 type, with increasing atomic number of an element

   (1) increase
   (2) weaken
   (3) remain unchanged
   (4) increase and then weaken

5. The electronic configuration of the nitrogen atom can be represented as

(1) $\mathrm{N}\!:$ (3) $\cdot\,\dot{\underset{\cdot}{\mathrm{N}}}\!:$

(2) $\dot{\mathrm{N}}\!:$ (4) $:\dot{\underset{\cdot\cdot}{\mathrm{N}}}\!:$

6. In the vapour state and at low temperatures phosphorus atoms combine into molecules:

(1) P_2 (3) P_6
(2) P_4 (4) P_8

7. Nitrogen exhibits the negative state of oxidation in the compound

(1) N_2O (3) NO_2
(2) NO (4) Na_3N

8. The stability of hydrogen compounds in the series NH_3—PH_3—AsH_3—SbH_3—BiH_3

(1) increases
(2) decreases
(3) remains unchanged
(4) decreases and then increases

9. Phosphine (hydrogen phosphide) can be prepared by hydrolysis of calcium phosphide according to the reaction ... .

10. A mixture of 15 litres of hydrogen and 15 litres of nitrogen is made reactive under the conditions of high pressure, high temperature, and employment of a catalyst. The reaction yields 50% of the theoretical for the main product. What gases and in what amounts will be found in the reactant mixture after the reaction ceases?

(1) 10 litres ammonia, 10 litres nitrogen
(2) 5 litres ammonia, 12.5 litres nitrogen, 7.5 litres hydrogen
(3) 5 litres ammonia, 5 litres nitrogen, 7.5 litres hydrogen
(4) 30 litres ammonia

11. In the laboratory, small amounts of ammonia can be prepared from ammonium chloride by the reaction ... .

12. Among the nitrides listed below, amphoteric one is

(1) Mg_3N_2 (3) P_3N_5
(2) AlN (4) Cl_3N

13. Which compound exhibits the largest mass percent of nitrogen?

(1) $NaNO_3$ (3) N_2O_3
(2) NH_4NO_3 (4) N_2O_5

14. Nitrogen(II) oxide is formed in the atmosphere during gas discharges. The N_2-O_2 interaction occurs by the mechanism ... .

15. Increased pressure shifts the equilibrium of the system described by the equation

$N_2 + 3H_2 \rightleftarrows 2NH_3$ (all gases)

so that

(1) more NH_3 (gas) is formed
(2) more N_2 (gas) evolves
(3) more N_2 (gas) and H_2 (gas) are released
(4) the amounts of the reactants and the products remain unchanged

16. The shape of the ammonia (NH_3) molecule is

(1) bent (3) planar
(2) linear (4) pyramidal

17. Hydrogen compounds of the VA Group elements have these boiling points (°C):

NH_3	PH_3	AsH_3	SbH_3
—33	—87	—55	—17

As can be seen from the above data, in this sequence the boiling point of ammonia does not agree with the general tendency for an increase due to:

(1) the ionic character of the chemical bond
(2) the metallic character of the chemical bond

(3) the presence of hydrogen bonds
(4) the effect of van der Waals forces

18. The molar mass (g/mole) of ammonium carbonate $(NH_4)_2CO_3$ is about

(1) 43.0 (3) 78.0
(2) 72.0 (4) 96.0

19. A free metal is formed by thermal decomposition of

(1) KNO_3 (3) $Pb(NO_3)_2$
(2) $Mg(NO_3)_2$ (4) $AgNO_3$

20. In the course of the reaction $NH_3 + H_2PO_4^- \rightleftarrows NH_4^+ + HPO_4^{2-}$ dihydrophosphate ion $H_2PO_4^-$ is

(1) a proton donor (3) a reducing agent
(2) a proton acceptor (4) an oxidizing agent

21. Which species undergoes oxidation in the reaction

$3Cu^0 + 8H^+ + 2NO_3^- = 3Cu^{2+} + 2NO + 4H_2O$?

(1) NO (3) H^+
(2) NO_3^- (4) Cu^0

22. Nitrogen(IV) oxide can react with

(1) sodium chloride
(2) oxygen
(3) hydrochloric acid
(4) calcium hydroxide

The reaction equation reads: ... .

23. Ammonia burns in oxygen to yield ... following the reaction ... .

24. Ammonia can be oxidized with oxygen of the air in the presence of a catalyst to give ... . The reaction equation is ... .

25. The salts of nitrous acid, e.g. $NaNO_2$, act as

(1) reducing agents only
(2) oxidizing agents only
(3) both, reductants and oxidants
(4) cannot exhibit redox properties

26. Sodium nitrite can react with potassium iodide in the acid solution with formation of oxidation-re-

duction products ... and ... according to the reaction ... .

27. Sodium nitrite can react with potassium permanganate in the acid solution to form the redox products ... and ... . The reaction equation reads: ... .

28. Nitric acid fails to react with

(1) Cu (3) Pt
(2) Zn (4) Fe

29. Concentrated nitric acid can react with

(1) CO_2 (3) C
(2) HCl (4) $Ba(OH)_2$

Here nitric acid reacts with substances ... thus exhibiting acidic properties, and with substances ... when it shows oxidation properties.

30. The molar mass (in g/mole) of calcium nitrate $Ca(NO_3)_2$ equals:

(1) 82 (3) 164
(2) 102 (4) 204

31. Copper chips react with concentrated nitric acid to yield the gas

(1) NO_2 (3) N_2O
(2) NO (4) NH_3

32. The reaction between the active metal magnesium and a very dilute solution of nitric acid leads to the reduction of the acid, chiefly to

(1) NO_2 (3) N_2O
(2) NO (4) NH_3

33. Nitrogen(IV) oxide molecules (greyish brown) can dimerize under certain conditions with the formation of a colourless liquid, N_2O_4. The heat of the dimerization reaction $2NO_2 \rightleftarrows N_2O_4$ is 55 kJ/mole. The conditions that should be imposed on the system to convert nitrogen(IV) oxide to the colourless dimer most completely are:

(1) cooling
(2) heating

(3) sunlight
(4) keeping at room temperature for a long time

34. Phosphorus oxidation with nitric acid follows the reaction ... .
35. Aqua regia is a mixture of three parts by volume of concentrated ... acid and one part of concentrated ... acid. It dissolves gold and platinum metals. Aqua regia reacts with gold in compliance with the reaction ... .
36. Chlorine reacts with nitrogen(II) oxide following the scheme:

$$NO + Cl_2 \rightarrow NOCl$$

The reaction temperature is such that all the reactants and the product are in the gaseous state. These are the data on the rate of the forward reaction for three runs conducted at the same temperature:

	Runs I	*Runs* II	*Runs* III
Initial pressure p (NO), kPa	50.0	100.0	50.0
" p (Cl_2), kPa	50.0	100.0	100.0
Initial rate v, kPa/s	0.5	4.0	1.0

The rate equation for this gas phase reaction has been found to equal ... .
37. The correct representation of the reaction rate vs concentration for the reaction

$$2NO_2 + H_2O = HNO_3 + HNO_2 \text{ (all gases)}$$

reads:

(1) $v = k\,[NO_2]^2\,[H_2O]$
(2) $v = k\,[NO_2]\,[H_2O]$
(3) $v = k\dfrac{[HNO_3][HNO_2]}{[NO_2]^2[H_2O]}$
(4) it is determined experimentally but cannot be derived from the net reaction equation

38. Nitrogen(V) oxide decomposes following the equation

$$2N_2O_5 \rightarrow 4NO_2 + O_2 \text{ (all gases)}$$

These are the experimental data:

Time, min	0	4	8	12	16
$[N_2O_5] \times 10^{-3}$, mole/litre	5.00	4.20	3.53	2.96	2.48

25% nitrogen(V) oxide is decomposed after:

(1) 3 min (3) 12 min
(2) 6 min (4) 18 min

39. In the equation for the reaction

$\ldots H_2SO_4 + \ldots P \rightarrow \ldots H_3PO_4 + \ldots H_2O + \ldots SO_2$

the coefficient for phosphorus is

(1) 1 (3) 4
(2) 2 (4) 5

40. Gunpowder is a mixture of potassium nitrate, sulphur, and carbon with a molar ratio of 2 : 1 : 3. The net equation for gunpowder combustion is ... .

41. A 26-cm^3 vessel contains gaseous nitrogen under a pressure of 233 kPa and a temperature of 27 °C. The nitrogen amount (mole) is

(1) 2.43×10^{-3} (3) 6.21×10^{-2}
(2) 2.43×10^{-2} (4) 2.4×10^{-5}

42. Gaseous nitrogen(V) oxide is decomposed according to the net equation

$2N_2O_5 = 4NO_2 + O_2$

The hypothetical reaction mechanism includes these steps ($\cdot NO_3$ is a radical):

(a) $N_2O_5 \overset{K}{\rightleftarrows} NO_2 + \cdot NO_3$ (equilibrium)

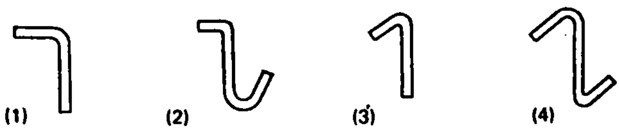
(b) $\cdot NO_3 \xrightarrow{k_1} O_2 + NO$ (slow step)

(c) $NO + \cdot NO_3 \xrightarrow{k_2} 2NO_2$ (rapid step)

The rate equation for nitrogen(V) oxide decomposition is ... .

43. Hydrolyses of nitrogen(III) fluoride and nitrogen (III) chloride follow the equations... and ... .

44. Which of these multi-purpose tubes



should be used for ammonia production in the laboratory? The schematic of an apparatus containing this tube for ammonia production in the laboratory can be presented as ... .

45. Phosphoric acid can be obtained by treating ground calcium phosphate with

(1) HCl (3) $NaOH$
(2) H_2SO_4 (4) HNO_3

The resulting reaction reads ... .

46. What amount of phosphorus (in g) can be produced from 3.1 kg of phosphorite mixed with coke and sand, which is calcined at 1500 °C for the purpose?

(1) 310 (3) 1240
(2) 620 (4) 3100

47. The mass percent of phosphorus in sodium hydrophosphate crystal hydrate $Na_2HPO_4 \cdot nH_2O$ is 11.56%. The crystal hydrate contains this number of molecules:

(1) $n = 0$ (3) $n = 7$
(2) $n = 1$ (4) $n = 12$

48. Nitrogen(I) oxide N_2O (laughing gas) can be obtained by thermal decomposition of

(1) NH_4Cl (3) $NaNO_3$
(2) NH_4NO_3 (4) $Cu(NO_3)_2$

49. 14.2 g of phosphorus(V) oxide were dissolved in 250 g of a solution of phosphoric acid (mass percent

9.8%). The mass percent of phosphoric acid in the resulting solution is equal to:

(1) 5.4 (3) 16.7
(2) 14.7 (4) 17.6

50. Write the formulas of the following fertilizers.

	Fertilizer	*Formula*
(1)	Phosphorite	...
(2)	Ammoniated superphosphate	...
(3)	Double superphosphate	...
(4)	Precipitate (dicalcium phosphate)	...

... is richest in phosphorus.

51. The Khibini apatite contains: 39.7% Ca, 18.4% P, 38.1% O, and 3.8% F. The quantitative composition of this apatite can be represented by the formula ... .
52. 1.98 g of ammonium sulphate was heated with excess sodium hydroxide to yield a gas. It was dissolved in a solution containing 5.88 g of phosphoric acid with the formation of the salt:

(1) ammonium dihydrophosphate
(2) ammonium hydrophosphate
(3) ammonium phosphate
(4) a mixture of ammonium phosphate and dihydrophosphate

53. Red phosphorus mixed with finely ground glass and glue is applied to the side surface of a matchbox. A match tip contains potassium chlorate and sulphur. The friction of the match tip against the side surface of the box causes an inflammation according to the chemical reaction ... .
54. The mineral fertilizer containing the largest amount of nitrogen is

(1) sodium nitrate
(2) potassium nitrate
(3) ammonium nitrate
(4) carbamide

This fertilizer is produced in the reaction ... .

55. Thermal decomposition of ammonium dichromate proceeds with the evolution of a variety of gaseous products according to the reaction equation

$$(NH_4)_2Cr_2O_7 \xrightarrow{T} \ldots$$

56. Phosphorus reacts with gaseous chlorine to yield PCl_3 (heat of formation, 280 kJ/mole) or PCl_5 (heat of formation, 367 kJ/mole). The heat of the reaction $PCl_3 \rightarrow PCl_5$ (kJ) equals:

(1) +87 (3) +174
(2) −87 (4) −174

57. The stability of the compounds in the series of phosphorus halides: PF_3—PCl_3—PBr_3—PI_3

(1) decreases
(2) increases
(3) remains unchanged
(4) decreases and then increases

58. Ammonia NH_3 is passed through a vessel containing water and yields

(1) a neutral solution
(2) an acidic solution
(3) a basic solution

Now replace ammonia NH_3 with phosphine PH_3 and answer the same question.

59. Arsenic can react with concentrated HNO_3 to undergo oxidation with the formation of

(1) AsH_3 (3) H_3AsO_3
(2) As_2O_3 (4) H_3AsO_4

60. **Bismuth reacts with dilute HNO_3 to form**

(1) $Bi(NO_3)_3$ (3) BiH_3
(2) $Bi(OH)_3$ (4) $HBiO_3$

61. Thermal decomposition of equal samples of nitrates (weighing 100 g each) liberated the maximal

amount of moles of gaseous products from

(1) $NaNO_3$ (3) $AgNO_3$
(2) $Pb(NO_3)_2$ (4) NH_4NO_3

62. In the laboratory, nitrogen is commonly produced by heating a mixture of saturated solutions of ... and .... The relevant reactions are ... and ....

63. Hydrolysis of phosphorus pentachloride PCl_5 yields

(1) HPO_3 (3) $H_4P_2O_7$
(2) H_3PO_3 (4) H_3PO_4

The equation for the hydrolysis reads ... .

64. Nitric acid is kept in dark-glass vessels, since sunlight decomposes it to

(1) NH_3 and O_2 (3) NO_2 and O_2
(2) NO and NO_2 (4) NO_2 and N_2O

65. Concentrated nitric acid is a strong oxidizing agent. Oxidation of hydrochloric acid follows the equation ... .

66. Nitrogen(III) oxide can be absorbed by sodium hydroxide solution with the formation of

(1) NO_2 and NO (3) $NaNO_3$
(2) $NaNO_3$ and $NaNO_2$ (4) $NaNO_2$

67. 142 g of phosphorus(V) oxide was dissolved in 500 g of orthophosphoric acid (mass percent of H_3PO_4, 10%). The mass percent of H_3PO_4 in the resulting solution became:

(1) 23.0 (3) 38.3
(2) 29.6 (4) 49.2

68. Write equations for the reactions describing these formations:

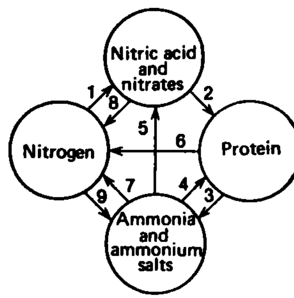
Nitrogen $\xrightarrow{(1)\ldots}$ Ammonia $\xrightarrow{(2)\ldots}$ Nitrogen oxide(II) $\xrightarrow{(3)\ldots}$ Nitrogen oxide(IV) $\xrightarrow{(4)\ldots}$ Nitric acid $\xrightarrow{(5)\ldots}$ Ammonium nitrate

69. Write equations for the reactions following the transformations:

Phosphorus $\xrightarrow{(1)\ldots}$ Magnesium phosphide $\xrightarrow{(2)\ldots}$ Phosphine $\xrightarrow{(3)\ldots}$ Phosphorus oxide (V) $\xrightarrow{(4)\ldots}$

$\longrightarrow$ Orthophosphoric acid $\xrightarrow{(5)\ldots}$ Calcium phosphate $\xrightarrow{(6)\ldots}$ Calcium dihydrophosphate

70. Nitrogen cycle in nature can be represented as the following scheme. Examine closely the scheme and write the names of the relevant processes and equations for the chemical reactions (with the arrows like those in the scheme), where it is possible.



2.4 Carbon and Silicon—Chemistry of Animate and Inanimate Nature

"As a constituent of compounds, carbon makes part of the so-called organic substances, i. e. a variety of substances that are contained in the body of any plant and animal. Carbon occurs in water and air as carbon dioxide and in the soil and the earth crust as carbonates and organic remnants ... ."

D.I. Mendeleev

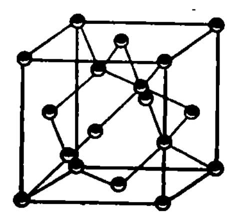
1. Atoms of Group IV p elements of the periodic system have the common electronic formula ..., where n is the number of the energy level.
2. In the series C—Si—Ge—Sn—Pb the non-metal properties of the elements

   (1) increase
   (2) weaken
   (3) remain unchanged
   (4) increase and then weaken

3. Carbon occurs freely in the form of three simple substances, each exhibiting a definite structure accounted for by the type of hybridization of the carbon atom. Indicate the structure (coordination, layer-type, or linear) and the type of hybridization for the substances listed below.

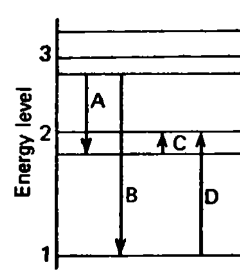
	Substance	*Structure*	*Hybridization type*
(1)	Diamond	. . .	. . .
(2)	Graphite	. . .	. . .
(3)	Carbene	. . .	. . .

4. The figure shows the crystal structure of silicon. Its crystal lattice is of the type of



(1) common salt
(2) perovskite
(3) zinc sulphide
(4) diamond

5. Electron transfer, in the course of a chemical reaction, from one sublevel to another as a result of carbon atom excitation is presented in the figure by the letter



(1) A
(2) B
(3) C
(4) D

6. The valence orbitals of the carbon atom in the methane molecule CH_4 can be described using the hybridization type

(1) sp
(2) sp^2
(3) sp^3
(4) d^2sp^3

which accounts for the following structure of the methane molecule:

(a) linear
(b) planar
(c) tetrahedral
(d) octahedral

7. The valence orbitals of the silicon atom in the silane molecule SiH_4 can be described using the hybridization type

(1) sp (3) sp^3
(2) sp^2 (4) d^2sp^3

This accounts for the following geometry of the silane molecule

(a) linear (c) tetrahedral
(b) planar (d) octahedral

8. Graphite exhibits a lower stability of its crystal lattice as compared with diamond. The heat of the conversion C (graphite) → C (diamond) can be estimated

(1) using the data of the studies of the graphite and diamond crystal structure
(2) based on the combustion data on reaction heats for graphite and diamond
(3) experimentally, employing a calorimetric setup to measure the heat of the conversion graphite → diamond
(4) if one compares graphite and diamond densities

9. The heat of diamond-to-graphite conversion has not been measured experimentally. The heats of combustion of 1 mole of diamond and 1 mole of graphite in oxygen are known:

(a) C (diamond) + O_2 (gas) = CO_2 (gas) + 395.5 kJ
(b) C (graphite) + O_2 (gas) = CO_2 (gas) + 393.4 kJ

Heat (in kJ/mole) of the conversion C (diamond) → C (graphite) is

(1) 0 (3) −2.1
(2) +2.1 (4) + 788.9

10. Silanes are less stable and more reactive than corresponding hydrocarbons. Given below are heats of formation of some compounds from simple substances:

Compound	*Heat of formation* (kJ/mole)
SiO_2 (crystal)	+908
SiH_4 (gas)	−35
H_2O (gas)	+241.8
O_2 (gas)	0

The heat of formation of a simple substance is zero. What is the heat of combustion (in kJ/mole) for silane?

(1) + 1184.8 (3) + 1426.6
(2) − 1184.8 (4) − 1426.6

11. Methane is liberated in the decomposition, by water, of the carbide

(1) CaC_2 (3) Al_4C_3
(2) BaC_2 (4) Ag_2C_2

12. In the Earth atmosphere, cosmic rays act to produce the β-radioactive isotope ^{14}C by the nuclear reaction:

$$^{14}_{7}N + \ldots \rightarrow {}^{14}_{6}C + \ldots$$

13. A piece of wood from a tomb was tested to reveal that the intensity of radioactive decay of carbon-14 isotope is 10 times less than that for a piece of fresh wood. The half-life (the average time interval required for one-half of any quantity of identical radioactive atoms to undergo radioactive decay) of carbon-14 is 5600 years. The age of the wood from the tomb was

(1) 9100 (3) 28 000
(2) 18 200 (4) 56 000 years

14. The radioactive decay rate for carbon-14 can be expressed by the equation $v = -\frac{dN}{dt} = \lambda N$ (where N is the number of atoms of ^{14}C isotope; t is the time; and λ denotes the radioactive decay constant). Integration of the equation yields the following relationship for the radioactive decay: $N = N_0 \exp \times (-\lambda t)$ (where N_0 is the number of carbon-14 atoms for the time $t = 0$).

Carbon, which participates in CO_2 cycle in nature, has 13.6 decays per minute for 1 g of carbon. When plant materials (e.g. trees) die off, they cease to participate in the CO_2 cycle, which reduces the decay rate. In 1983, the carbon decay rate in two pieces of wood from a viking ship was measured to give 12.0 decays per minute for 1 g of carbon. The tree from which the vikings had built their ship was cut in

(1) 431 (3) 1035
(2) 948 (4) 1465

15. Assuming the inaccuracy of measuring the carbon decay rate (12.0 decays per minute for 1 g of carbon) to be $\pm$ 0.2, the error in the determination of the tree age in Problem 14 is

(1) $\pm$ 137 (3) $+$ 139, $-$137
(2) $\pm$ 139 (4) $-$ 139, $+$ 137 years

16. Finely ground and thoroughly mixed magnesium (12 g) and silicon(IV) oxide (12 g) were ignited to yield a mixture containing (in moles)

(1) 0.2 Si, 0.4 MgO, and 0.1 Mg
(2) 0.15 Si, 0.4 MgO, and 0.05 Mg_2Si
(3) 0.05 Si, 0.2 MgO, and 0.15 Mg_2Si
(4) 0.1 Si, 0.4 MgO, and 0.1 Mg_2Si

17. Rain water is characterized by an important parameter, which is the pH value; this parameter is controlled by an equilibrium with atmospheric CO_2. As a rule, rain water pH is

(1) < 7 (3) about 7
(2) > 7 (4) independent of CO_2 (atmospheric)

18. An interaction between metal carbonate and acid yields

(1) C (solid) (3) CO (gas)
(2) O_2 (gas) (4) CO_2 (gas)

19. Two gases of an approximately equal density react to produce water and sand. The equation for this reaction reads ... .

20. Preparation of carbon dioxide from marble in Kipp's apparatus rules out the use of

(1) dilute hydrochloric acid
(2) dilute sulphuric acid
(3) dilute nitric acid
(4) acetic acid

21. The mass (in g) of calcium carbonate needed to prepare 44.8 l of carbon dioxide measured at STP is

(1) 200.0 (3) 100.0
(2) 150.0 (4) 50.0

22. Formation of CO in the reaction

$C \text{ (solid)} + CO_2 \text{ (gas)} \rightleftarrows 2CO \text{ (gas)} - 119.8 \text{ kJ}$

is favoured by

(1) elevation of T and P
(2) elevation of T and reduction of P
(3) decrease in T and increase in P
(4) decrease in T and P

23. Which scheme is most accurate in representing the electron dot formula of the carbon dioxide molecule during the formation of chemical bonds in it?

24. Silicon can be obtained by heating sand ... vigorously in an electric furnace with calcium carbide ... . The reaction equation reads ... .

25. In a mixture of CO and CO_2 gases, the carbon-to-oxygen mass ratio is 1 : 2. The mass percent (ω, %) of the carbon(II) oxide in this mixture amounts to ..., and that of the carbon(IV) oxide is ... . The volume percent (φ, %) of the carbon(II) oxide is ..., and that of the carbon(IV) oxide, ...

26. Coal mined in some coal field shows this composition (%): C, 82.2; H, 4.6; S, 1.0; O, 4.0; N, 1.2; H_2O, 1.0;

and ash, 6.0. Combustion of 1 kg of this coal needs air of the volume (in m^3) about

(1) 1.5 (3) 7.5
(2) 1.7 (4) 8.5

27. Slaked lime is produced from limestone in the reactions ... and ... .
28. On long storage in the air slaked lime gradually converts to ... by the reaction ... .
29. On long standing in glass vessels alkali solutions show a turbidity due to the reaction ... occurring therein.
30. Complete combustion of 1 mole of carbon to carbon(IV) oxide releases 393.5 kJ of heat, and incomplete combustion of 1 mole of carbon leading to carbon(II) oxide evolves 110.5 kJ. The heat of formation(in kJ) of carbon monoxide in the reaction between 1 mole of CO_2 and 1 mole of red hot carbon is

(1) + 504.0 (3) + 172.5
(2) − 283.5 (4) − 172.5

31. Stalactites and stalagmites are known to form in underground caves as a result of $CaCO_3$ deposition. Interaction of limestone with water and carbon dioxide yields $Ca(HCO_3)_2$ solution (the reaction is reversible and reads ...), which leaks through the cracks in the cave roof. Further, water evaporates and CO_2 volatilizes. The limestone deposition occurs due to the low air pressure. The equilibrium of the above reversible reaction is shifted to the ... .
32. Complete hydrolysis of $SiCl_4$ occurs through consecutive addition of water molecules and splitting of HCl molecules, resulting in the formation of

(1) H_4SiO_4 (3) $SiCl_3(OH)$
(2) $SiCl(OH)_3$ (4) $SiCl_2(OH)_2$

33. In an ordinary charged fire extinguisher, a steel tank is filled with a concentrated solution of sodium bicarbonate with an admixture of substances contributing to foaming. The glass bottle in the top of the

steel tank, which is broken when the tank is turned over to start putting out the fire, contains

(1) conc. KOH
(2) conc. H_2SO_4
(3) conc. $Ca(OH)_2$
(4) conc. HCl

34. The major reason of the crucial role of carbon in the life origination is

(1) its high abundance on the Earth
(2) the existence of a variety of allotropic modifications
(3) the ability to form long chains of atoms
(4) its high melting point

35. Acetylene burns in oxygen to yield

(1) carbon monoxide and water
(2) carbon (soot) and water
(3) carbon dioxide and water
(4) carbon dioxide and hydrogen

36. A chemical compound answering the simplest empirical formula CH_2 exhibits a relative molecular mass of 28. The chemical formula of the compound is

(1) CH_2
(2) C_2H_4
(3) C_2H_2
(4) CH_4

37. The coefficients in the equation for the ethane combustion reaction

$$\ldots C_2H_6 + \ldots O_2 \rightarrow \ldots CO_2 + \ldots H_2O$$

are

(1) 1, 3, 2, and 3
(2) 1, 6, 2, and 6
(3) 2, 6, 4, and 5
(4) 2, 7, 4, and 6

38. The combustion of 1 mole of acetylene (C_2H_2) requires approximately this volume (in litres) of the air (measured at STP):

(1) 45.0
(2) 280.0
(3) 336.0
(4) 660.0

39. Complete combustion of a hydrocarbon (C_nH_m) in the air gives

(1) CO and H_2 (3) CO and H_2O
(2) CO_2 and H_2 (4) CO_2 and H_2O

40. Vaporization of 2.00 g of liquid ethanol at its boiling point (78 °C) occurs with heat absorption in an amount of (in kJ)

(1) 539.2 (3) 852.7
(2) 652.0 (4) 1705.4

The heat of ethanol vaporization is 852.7 kJ/g.

41. The noxious gas phosgene shows the following elementary composition (in mass percent): C, 12.1; O, 16.2; and Cl, 71.7. Its chemical formula is ....

42. The interaction of ... with ... over activated carbon at 120 °C leads to the formation of a very toxic gas—carbonyl chloride (phosgene) .... This substance can undergo slow hydrolysis with water in compliance with the equation ....

43. A flask was filled with gaseous carbon(IV) chloride and weighed at a definite temperature and pressure. Further, the carbon(IV) chloride was removed from the flask and oxygen was placed instead, at the same temperature and pressure conditions. The mass of the carbon(IV) chloride sample was

(1) equal to the mass of the oxygen sample
(2) less by a factor of 5
(3) larger by a factor of 5
(4) was half the mass of the oxygen sample

44. When ... is added to slaked lime the "slaking effect" can be observed. The equation for the relevant reaction is ....

45. Carbon dioxide was passed through limewater for an appreciable length of time. The initial process was ... which was followed by the process .... The clear solution obtained was evaporated and the dry residue appeared to be the substance of the composition ....

46. In lime kilns, CO_2 is collected by passing flue gases through potassium carbonate solution; the reaction

equation reads .... The solution obtained after the saturation with the flue gases is heated to cause the reaction . . . .

47. Gaseous $COCl_2$ is placed in an empty vessel under a pressure of a. The following equilibrium is attained in the vessel at a constant temperature:

$2COCl_2$ (gas) $\rightleftharpoons$ C (graphite) + CO_2 (gas) + $2Cl_2$ (gas)

If the partial pressure of CO_2 in the mixture is x, the equilibrium constant can be defined as

(1) $K_e = 4x^3/(a - 2x)^2$ (3) $K_e = 2x^2/(a - 2x)^2$
(2) $K_e = 4x^3/(a - x)^2$ (4) $K_e = x^3/(a - 3x)^2$

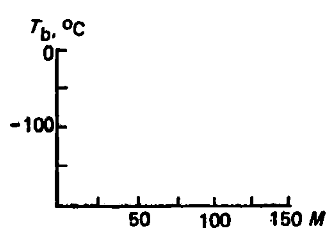
48. Hyperpure silicon is used in transistors. Its preparation involves conversion of a chemically pure silicon to silicon chloride according to the reaction ... , whose product is reduced with hydrogen .... .

49. Railroad men use sodium fluoride as a preserving agent for wood. The substance can be obtained by heating a mixture of calcium fluoride, soda, and sand in the reaction ....

50. The names and empirical formulas of some silicon minerals are given below. Express their composition in the form of oxides.

Name of the mineral	*Empirical formula*	*The mineral formula as oxides*
(1) Orthoclase	$KAlSi_3O_8$	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$
(2) Serpentine	$Mg_3H_4Si_2O_9$	. . .
(3) Albite	$Na_2Al_2Si_6O_{16}$	. . .
(4) Willemite	Zn_2SiO_4	. . .
(5) Anorthite	$CaAl_2Si_2O_8$	. . .

51. The boiling point of germanium hydride GeH_4 is -90 °C. Plot curve showing an approximate dependence of the boiling points T_b of IVA Group hydrides (CH_4, SiH_4, GeH_4, and SnH_4) on the molar mass M of a compound.



52. Beryllium carbide ... can be regarded as a methane derivative (methanide), and barium carbide ..., as an acetylene derivative (acetylenide). The interaction of these carbides with water occurs in the reactions ... and ....

53. Heats of the conversion of diamond and graphite into gaseous isolated carbon atoms are 713 and 715 kJ/mole, respectively. Based on these data it may be inferred that the bond energy of carbon atoms in diamond is ... kJ/mole, and that in graphite, . . . kJ/mole.

54. Silicon is readily soluble in alkali solutions. Here an oxidizing agent is

(1) Na^+ ions	(3) silicon
(2) water	(4) OH^- ions

55. In the laboratory, silicon is prepared in the reaction between SiO_2 and ... described by the equation .... On an industrial scale, the approach is that of reducing SiO_2 with ... in electrical furnaces according to the reaction equation ....

56. In refrigerating plants, a methane derivative, Freon-12, is used as a cooling agent, whose boiling point is —30 °C. Its formula is

(1) CCl_4	(3) CF_2Cl_2
(2) CF_4	(4) CH_3Cl

57. In the laboratory, magnesium cuttings have ignited. The fire can be put out by

(1) water
(2) using a carbonic acid fire extinguisher
(3) sand
(4) sodium bicarbonate

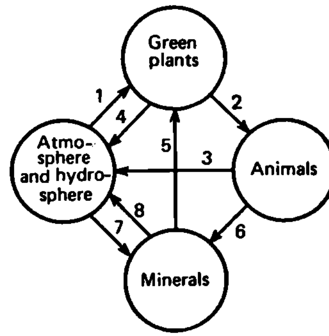
58. Describe by chemical equations the essential reactions in making SiO_2 from Si

$$Si \xrightarrow{(1)...} SiO_2 \xrightarrow{(2)...} Na_2SiO_3 \xrightarrow{(3)...} H_2SiO_3 \xrightarrow{(4)...} SiO_2$$

59. Write equations to show the reactions that underlie these conversions:

$$C \xrightarrow{(1)\ldots} CO_2 \xrightarrow{(2)\ldots} CaCO_3 \xrightarrow{(3)\ldots} CaO \xrightarrow{(4)\ldots} CaC_2$$

60. The carbon cycle in nature can be represented as the following scheme. Examine closely the scheme and name the processes depicted by the arrows and numbered *1* through *8*



2.5 Metals

"Metals open the interior of the earth to fertility; metals help us in catching the earth and sea animals for our food; metals supply the merchants with coins .... In short, neither artistic handicraft, nor any other occupation can do without metals."

M.V. Lomonosov

1. The most widespread metal in the Earth crust is

(1) Fe (3) Al
(2) Ti (4) Ca

2. The following sequence of the elements are not metals:

(1) Ca, Zn, Cd (3) B, As, Te
(2) Ga, In, Tl (4) W, Bi, Os

3. Among the metals K, Cd, Ca, Co, Mn, Li, Au, Zn, Mg, Cu, the light ones are ... , and the heavy ones are ....

4. Name the metals:

(1) the heaviest metal is ... and the lightest, ...
(2) the highest-melting metal is ..., and the lowest-melting one is ...
(3) the hardest metal is ... and the softest metal, ...

5. Among the elements K, Rb, Ca, Sr, the atom of ... exhibits the highest energy of the outermost electron detachment.
6. Lithium combines vigorously with hydrogen: a small amount of the metal can bind a large volume of the gas. Lithium hydride tablets are used as a handy source of hydrogen during accidents over the seas: they decompose under the action of water and fill life belts and boats with hydrogen. The chemical interaction between lithium hydride and water obeys the reaction equation ....
7. The crystal structure of metals accounts for their most crucial properties. For instance, the alkali metals K, Rb, and Cs show

(1) a body-centered cubic structure
(2) a hexagonal close-packed structure
(3) a face-centered cubic structure
(4) different cubic modifications

8. Metal A (relative atomic mass, 58.71) of a mass of 1.49 g reacts with a simple substance B weighing 6.44 g to form a compound AB_2 with no residue. AB_2 appears to be

(1) $CuCl_2$ (3) $NiBr_2$
(2) CaF_2 (4) NiI_2

9. In electrical engineering, electric lamps are manufactured using a metallic filament made of

(1) Al (3) Fe
(2) Cu (4) W

since this metal shows

(1) the highest electrical conductivity
(2) the highest heat conductivity

(3) the lowest melting point
(4) the highest melting point

10. The interaction of 3.42 g of an alkali metal with water liberates 448 cm^3 of hydrogen (at STP). The alkali metal is

(1) lithium Li
(2) potassium K
(3) sodium Na
(4) rubidium Rb

11. Combustion of sodium in oxygen yields a substance of the composition ..., and combustion of iron in oxygen gives ....
12. A sample containing 0.850 g of a mixture of solid lithium and calcium hydrides reacts with water to form 1.200 litres of hydrogen (at STP). Lithium hydride participates in the reaction ..., and calcium hydride, in the reaction .... The mass percent ω of lithium hydride in the initial mixture is . . . %.
13. On prolonged storage in the air, the mass of copper powder (initial mass, 10.36 g) increased to 11.86 g. The conversion being complete, an oxide of the composition ... was produced.
14. Metal M forms an oxide of the composition M_2O_3. An atom of M in the ground state exhibits this valence-shell structure:

(1) ns^2np^1
(2) ns^2np^3
(3) ns^2np^2
(4) ns^1

15. Sodium has been discovered by

(1) H. Davy
(2) H. Cavendish
(3) K. Scheele
(4) J. Priestley

16. Taking into account that cesium has a coordination number of 8, draw a fragment of cesium chloride crystal lattice ..., where filled circles are cesium ions and open circles, chloride ions.
17. Halides of the alkali metals form in the reaction between an alkali metal and .... For example, potassium bromide is obtained from the reaction whose equation reads ....

18. Below are given the melting points (°C) for alkali metal halides:

	Li	Na	K	Rb	Cs
F	870	992	857	775	684
Cl	614	801	776	717	646
Br	549	755	730	682	636
I	446	662	686	642	621

There is a general decrease in the melting points of the halides from fluorides to iodides. This can be attributed to a regular

(1) increase in the ionic radii of the alkali metals
(2) decrease in the ionic radii of the halogens
(3) increase in the sums of ionic radii of the alkali metals and halogens
(4) decrease in the sums of ionic radii of the alkali metals and halogens

19. How many fluorides can an element with an atomic number of 83 form? Write their chemical formulas.

20. It has been found that a sample of salt A weighing 5 g contains 0.6 g of carbon and 2 g of metal B. The latter can react with a great excess of water to form limewater (a well-known reagent). The gas forming on combustion of salt A can react with this reagent. Metal B and salt A are, respectively:

(1) Ba, $BaCO_3$ (3) Na, Na_2CO_3
(2) Ca, $CaCO_3$ (4) Mg, $MgCO_3$

21. Tell how many moles of aluminium(III) oxide are formed from one mole of aluminium in the reaction

$4Al + 3O_2 \rightarrow 2Al_2O_3$

(1) 0.5 (3) 3.0
(2) 2.0 (4) 4.0

22. The mass percent of iron in iron(III) oxide is

(1) 40.0 (3) 68.4
(2) 55.8 (4) 70.0

23. A beaker contained 60 g of a 10% solution of hydrochloric acid; 8 g of iron filings was added. The beaker was left to stay overnight in the air. In the morning,

it was found that the substance formed in the beaker was

(1) $FeCl_2$ (3) $Fe(OH)Cl_2$
(2) $Fe(OH)Cl$ (4) $Fe(OH)_2Cl$

24. In radio engineering, printed-circuit boards are produced by etching copper plates with iron(III) chloride. Describe this process by a chemical equation ....

25. 182.5 g of hydrochloric acid with a mass percent of HCl amounting to 10% was spent for complete dissolution of 16 g of iron and presumably its oxidation product. The mass of the released hydrogen was 0.25 g. It was found that hydrochloric acid was used to dissolve

(1) iron (3) Fe/Fe_2O_3 mixture
(2) Fe/FeO mixture (4) Fe/Fe_3O_4 mixture

26. The name of the chemical compound CaH_2 is

(1) calcium amide (3) calcium hydrate
(2) calcium hydride (4) calcium hydroxide

27. M is a silvery metal; A, B, and C are its compounds. The metal compound B is coloured reddish and employed as a dye. Based on these data and this scheme

$$\begin{tikzcd} M \arrow[r, "+O_2", "T"'] & A \arrow[r, "+O_2", "T"'] & B & C \arrow[l, "T"', "-O_2"] \\ & & A + C \arrow[u, "T"'] & \end{tikzcd}$$

what metal is M? Name its compounds A, B, and C.

28. Once in a storehouse, aluminium workpieces were spoiled because the ceiling was whitewashed with slaked lime, and the aluminium workpieces remained unprotected against spattering. The damage can be attributed to the fact that

(1) the workpieces got clogged up with the whitewashing solution
(2) a chemical reaction occurred between the workpieces and the slaked lime solution

(3) the aluminium workpieces corroded in the air in the presence of moisture
(4) the workpieces have reacted with water

If you choose answers (2) or (4), write equation for the reaction.

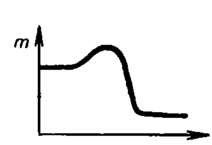
29. Two flasks without labels contain magnesium and zinc granules. The metals can be identified sufficiently accurately

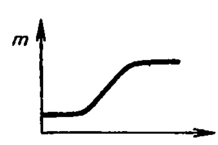
(1) by measuring the volume of the hydrogen evolved in the interaction of the metal samples of equal mass with hydrochloric acid
(2) visually, comparing the colour of the metallic granules
(3) by weighing a single granule of each metal
(4) by observing the difference in the interaction of the metals with dilute H_2SO_4 and NaOH solutions at ambient conditions (room temperature)

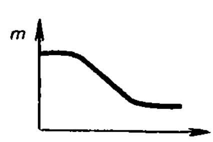
30. An unknown metal sample weighing 13 g was treated with dilute nitric acid. Then excess potassium hydroxide solution was added to the solution obtained to release 1.12 litres of a gas (the gas volume measured at STP). Name the metal that was dissolved in HNO_3:

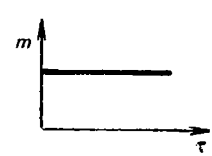
(1) Zn (3) Cu
(2) Mg (4) Fe

31. A copper plate was introduced into a red-hot fusr nace. Which curve reflects a change in the plate mas- m on oxidation of copper to copper(II) oxide?

(1)


(3)


(2)


(4)


32. In electrical engineering, use is made of this physical property of copper and aluminium:

(1) heat conductivity
(2) ductility
(3) pliability
(4) electrical conductivity

33. Which of the properties of titanium listed below are used in modern aircraft construction?

(1) heat conductivity and electrical conductivity
(2) resistance to corrosion and strength
(3) non-magnetic property
(4) high affinity for oxygen

34. Titanium was first obtained by

(1) the Swedish scientist Berzelius
(2) the French chemist Moissan
(3) the American chemist Hunter
(4) the Russian scientist Kirillov

35. The metal ..., by virtue of the characteristic property ..., is used in a physical apparatus for measuring, for example, temperature and pressure which have found extensive application in the home and in industry.

36. Filaments in incandescent lamps are made of ... and electric wires that conduct electricity, of ... or ....

37. A sample of a binary alkali metal compound weighing 3.55 g and containing 55% of the metal reacts with carbon(IV) oxide to release 1680 cm^3 of oxygen. The alkali metal in the binary compound is

(1) Li (3) K
(2) Na (4) Rb

and the binary compound formula reads ... .

38. The contacts for certain radio parts are coated with gold to

(1) increase the stability of the product
(2) make the product more expensive
(3) protect the contacts against oxidation
(4) protect the apparatus against radio interference

39. The mass percent of gold in an 18-carat golden article is

(1) 25 (3) 75
(2) 50 (4) 100

40. Which of the components of the polluted city air has the most pronounced corrosive effect on the metals (especially at a high humidity)?

(1) CO_2 (3) CO
(2) N_2 (4) SO_2

41. Which of the metals listed below is most low-melting?

(1) Hg (3) Ga
(2) Na (4) Cs

42. Which of these metals reacts most vigorously with oxygen at room temperature?

(1) Fe (3) Ag
(2) Hg (4) Cu

43. Metallic copper can react with

(1) hydrogen (3) oxygen
(2) carbon(IV) oxide (4) nitrogen

The interaction is described by the equation ....

44. Which of the metals given below can displace hydrogen from water at room temperature?

(1) Copper (3) Sodium
(2) Iron (4) Silver

45. Sodium dissolves in water to yield a solution of

(1) sodium (3) sodium hydroxide
(2) sodium oxide (4) sodium hydride

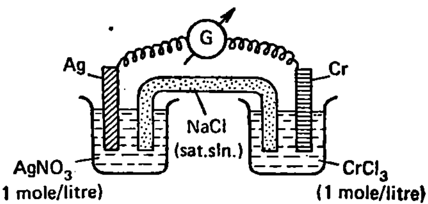
46. It is common knowledge that calcium dissolves in water more readily than in dilute sulphuric acid. This is because

(1) $CaSO_4$ is less readily soluble than $Ca(OH)_2$
(2) sulphuric acid is a less active chemical compound
(3) calcium reacts with sulphuric acid
(4) $Ca(OH)_2$ fails to form under these conditions

47. The conversion $Al^0 \rightarrow Al^{3+}$ can be realized by the scheme ....

48. The electromotive force (E, V) in the electrochemical chain $Cr^0 + 3Ag^+ \rightarrow Cr^{3+} + 3Ag^0$ is

(1) −0.06
(2) +0.06
(3) −1.54
(4) +1.54



$Cr^{3+} + 3\bar{e} \rightarrow Cr^0$; $E^0 = -0.74$ V
$Ag^+ + \bar{e} \rightarrow Ag^0$; $E^0 = +0.80$ V

49. For the ground coating of ceilings and walls use is made of a solution of

(1) NaCl
(2) $FeSO_4$
(3) $CuSO_4$
(4) $Ca(OH)_2$

This solution is not recommended to store in iron buckets or tanks because the chemical process described by the reaction equation ... will occur.

50. A sample of a rubidium-zinc alloy weighing 10 g was placed in 0.1 litre of water. As a result, 1.12 litres of a gas (at STP) evolved. The alloy composition is: ... % Rb, and ... % Zn.

51. Electrolysis of a solution of nickel sulphate (metallic nickel is made the anode and graphite, the cathode) involves the following electrode reactions:
at the cathode: ...
at the anode: ...

52. Electrolysis of 1 litre of copper(II) chloride solution yielded 12.7 g of copper at the cathode. The solution density being $\rho \approx 1$ g/cm^3, the volume (in litres) of the gas evolved at the anode (measured at STP) is

(1) 2.24
(2) 4.48
(3) 6.72
(4) 8.96

53. Four samples of an iron alloy were placed in

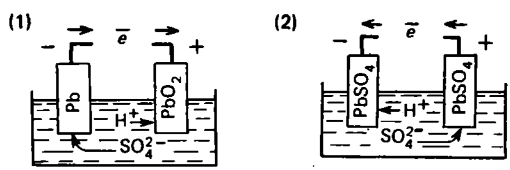
(1) distilled water
(2) water saturated with oxygen
(3) water saturated with a mixture of oxygen and carbon(IV) oxide
(4) water through which gaseous hydrogen has been passed

The alloy corrosion is most vigorous in the case ....

54. White metallic tin, on long standing in a freezer, converts to grey powder (this phenomenon was once called "tin pest"). This transformation is related to

(1) a change in the crystalline structure of tin
(2) an interaction with nitrogen of the air at low temperatures
(3) a change in the partial pressure of oxygen in the air
(4) an interaction with water vapour contained in the humid air

55. Scheme ... shows charging of a lead storage cell, and scheme ..., its discharging.



56. Which metal among those listed below cannot react with concentrated nitric acid?

(1) Cu (3) Cr
(2) Ag (4) Zn

57. This metal fails to react with concentrated sulphuric acid:

(1) Cu (3) Mg
(2) Fe (4) Zn

58. Hydrochloric acid cannot react with

(1) Cu (3) Al
(2) Fe (4) Zn

59. Which metal cannot react with water?

(1) Ca (3) Fe
(2) Ni (4) Na

60. Four test tubes contain powdered copper(II) oxide, iron(III) oxide, silver, and iron. To detect these substances, you should use only one reagent (choose it among those listed below), adding it to each test tube as a solution:

(1) NaOH (3) H_2O
(2) HCl (4) Na_2CO_3

61. To a powdered mixture of two simple substances of the opposite chemical nature (silvery-white substance A and dark-grey substance B) added are a few drops of water, which is a catalyst for this reaction. The substances react vigorously to form a compound of the composition AB_3. Name the initial substances and write an equation for this reaction.

62. Which pair of substances given below (an electrolyte reactant is in the form of a solution) are capable of reacting with each other?

(1) Zn and $MgCl_2$ (3) Au and $AgNO_3$
(2) Pb and $ZnSO_4$ (4) Fe and $CuCl_2$

63. A sample of a metal weighing 13.7 g reacts with water with the evolution of 2.24 litres of a gas (at STP). The metal cation bears a charge of +2. The metal is

(1) Mg (3) Sr
(2) Ca (4) Ba

64. A mixture of copper and iron was treated with concentrated nitric acid to release 4.48 litres of a gas. When hydrochloric acid was added to the mixture, 2.24 litres of a gas evolve (the gas volumes were mea-

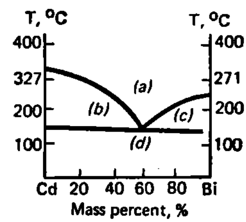
sured at STP). The mass (in g) of the copper-iron mixture was

(1) 5.6 (3) 11.95
(2) 6.35 (4) 18.3

65. Melted metals react with each other when mixed with the formation of chemical compounds such as $CuZn_3$, Na_2Pb, and Ca_3Sb_2.
These compounds are known as

(1) solid solutions
(2) intermetallic compounds
(3) intercalation compounds
(4) alloys

66. The figure shows a phase diagram for two metals (bismuth and cadmium). Indicate the regions (*a* through *d*) corresponding to the phase states of the cadmium-bismuth system:



Change of a state for the system	*Region*
(1) A mixture of crystalline Cd and Bi	...
(2) Liquid (melt)	...
(3) Liquid melt + solid Bi	...
(4) Liquid melt + liquid Cd	...

67. Electrochemical corrosion of metals, which is highly deleterious, is

(1) the destruction of metal when it combines with nitrogen oxides
(2) combination of metal with oxygen of the air
(3) metal destruction in an electrolyte solution with the formation of an electric current inside the system
(4) the combination of metal with sulphur(IV) and sulphur(VI) oxides

68. The corrosion rate of metallic constructions substantially depends on the nature of an electrolyte solu-

tion. For example, a metallic article will corrode most readily if an electrolyte contains

(1) an oxidant in an acidic medium at elevated temperature
(2) a reductant in an acidic medium at moderate temperature
(3) an oxidant in a basic medium at low temperature
(4) a reductant in a basic medium at elevated temperature

69. Corrosion of metals is highly detrimental to national economy. It may be inhibited by these major methods: ....

70. Complete mutual solubility of gold and silver can be attributed to the fact that

(1) both metals are noble
(2) the metals have similar physical properties
(3) the atoms of both metals show complete accommodation of *d* orbitals and belong to the Group I of the periodic table
(4) these metals have identical crystal structures and nearly equal atomic radii

71. White gold, which is commonly used in jewelry making, is an alloy of

(1) gold and silver (3) gold and copper
(2) gold and nickel (4) silver and copper

72. Alloy steels are iron-carbon alloys whose distinctive properties are due to the presence of one or more elements other than carbon. Cr and V, Mo and W, Cr and Ni, and Mn serve as the impurity metals. Which of these impurities should be used to produce steel exhibiting the properties given below?

Property	*Articles*	*Dopes*
(1) Extreme hardness	Crushers, safes	...
(2) Tenacity and flexibility	Automobile engines, spindles, casings	...
(3) Resistance to corrosion	Stainless steel	...

73. Aircraft industry and other fields of modern engineering make good use of aluminium-base alloys. Duralumin contains ... .

74. If some mercury(II) chloride solution is applied to an aluminium plate, after a time the plate gets warm and a film appears on its surface. Describe the processes that occur on the plate by the equations of chemical reactions:

Process	*Reaction equation*
(1) Interaction between Al and $HgCl_2$	...
(2) Amalgam formation	...
(3) Oxidation in the air	...

75. In a 500-cm^3 conical flask equipped with a Bunsen valve, a dropping funnel, and an exhaust pipe placed are a solution of chromium(III) chloride acidified with hydrochloric acid and metallic zinc powder. The space over the reacting mixture is filled with a noble gas. After the solution has turned bright blue, an excess of sodium hydroxide solution is added to yield a precipitate containing primarily

(1) $Cr(OH)_3$ (3) $Zn(OH)_2$
(2) $Cr(OH)_2$ (4) $Cr(OH)_2/Zn(OH)_2$ mixture

76. Copper forms alloys with a variety of metals. The most significant alloys are bronzes, German silver, brass, and coin alloys ("silver" change). Name the alloys answering the following compositions.

Alloy composition	*Name*
(1) 60% Cu and 40% Zn	...
(2) 68% Cu, 30% Ni, 1% Fe, and 1% Mn	...
(3) 90% Cu and 10% Sn	...
(4) 80% Cu and 20% Ni	...

77. Metallic platinum is stable to the action of concentrated acids serving as oxidizing agents (HNO_3 and H_2SO_4). It can be dissolved only on heating in ... . The equation for the reaction describing dissolution of the metal in this reagent reads ....

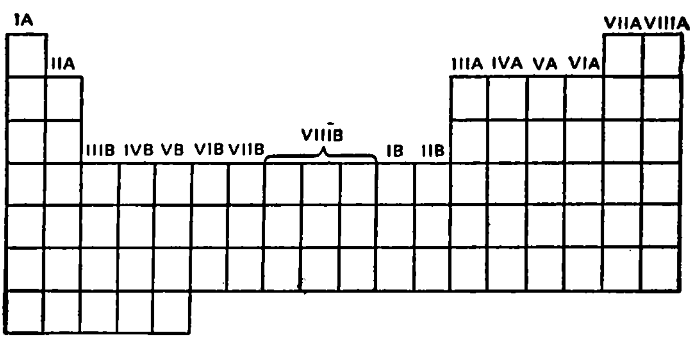
78. The metallic properties of the elements in the sequence Cr—Mo—W, with an increase in the atomic number of the element

(1) increase
(2) weaken
(3) practically remain unchanged
(4) weaken and then increase

79. In a compact state under ordinary conditions, vanadium, niobium, and tantalum metals differ by their

(1) ability to be oxidized with oxygen of the air
(2) ability to react with acid solutions
(3) ability to react with alkali solutions
(4) high chemical resistance to various chemical effects

80. Fill the matrix (fragment) of the periodic table with the metal symbols you know.



Chapter 3

Do You Know Chemical Engineering?

3.1 Production of Most Important Chemical Substances

"At all times, the question, What materials should we create and what properties should be imparted to them, has always been and will always be inseparable from the question, What method is to be used for the purpose. Engineering—the science dealing with the industrial production—can give an answer to this cardinal question."

Academician N.M. Zhavoronkov

1. Nitric acid in industry is prepared in several steps:

   (1) preparation of an ammonia-air mixture
   (2) oxidation of ammonia to nitrogen(II) oxide
   (3) oxidation of nitrogen(II) oxide to nitrogen(IV) oxide
   (4) absorption of nitrogen(IV) oxide with water yielding nitric acid

   Step ... proceeds in a contact apparatus in the presence of a catalyst. This reaction is
   (a) endothermic
   (b) exothermic

   In an absorption tower, water is supplied from the top and the gas mixture, from the bottom. Step ... of the process with an excess of oxygen is described by this equation of the reaction: ....

2. During the industrial preparation of nitric acid the reaction ... occurs in an oxidation tower with

   (1) the absorption of heat
   (2) the release of heat

3. The optimal ammonia-oxygen ratio (moles) is 1:2 in a mixture for preparing nitrogen(II) oxide with

platinum as catalyst. In the mixture, oxygen is taken

(1) in deficiency
(2) in excess
(3) in the stoichiometric ratio of the initial components

4. The contact process for the manufacture of sulphuric acid involves a variety of sulphur-containing materials, e.g. pyrite, native sulphur, sulphur-containing gases, scraps of the non-ferrous metallurgy, and sulphides of non-ferrous metals. Sintering of pyrite in a fluidized bed represents a chemical reaction described by the equation .... In a contact apparatus in the presence of a catalyst at 450 °C the process ... occurs. To date, ... is commonly used as catalyst. In an absorption tower, sulphur(VI) oxide is absorbed by concentrated sulphuric acid, and the main product ... is thus produced.

5. Available is a 96% solution of sulphuric acid (density, 1.84 g/cm^3). To produce 500 g of the solution with a mass percent of sulphuric acid equal to 5% we should mix

(1) 495 cm^3 H_2O and 5 cm^3 H_2SO_4
(2) 474 cm^3 H_2O and 14 cm^3 H_2SO_4
(3) 474 cm^3 H_2O and 26 cm^3 H_2SO_4
(4) 475 cm^3 H_2O and 25 cm^3 H_2SO_4

6. Ammonia is synthesized from a nitrogen-hydrogen mixture as the initial material. The catalyst-induced interaction between the gases proceeds in a synthesis tower at an elevated temperature and high pressure according to the reaction equation .... The reaction conditions are: temperature, ...; pressure, ...; catalyst, ...
The yield (in %) of the major product (ammonia) is

(1) 10-20 (3) 50-60
(2) 30-40 (4) 70-80

7. Phosphoric acid is prepared from phosphorite. The reaction equation reads:

$Ca_3(PO_4)_2 + \ldots \rightarrow CaSO_4\downarrow + \ldots$

8. Native calcium phosphate serves as raw material in the preparation of phosphorus in electrical furnaces by roasting it with sand and carbon. The net equation of the process is

$Ca_3(PO_4)_2 + 3SiO_2 + 5C = \ldots$

9. In industry, hydrochloric acid is produced by the synthetic and sulphate methods. In the former case, hydrogen chloride is formed in the interaction of ... with .... In the latter, by the reaction ...
10. In industry, silicon is manufactured by reducing silicon dioxide with carbon in electrical furnaces. The reaction products are

(1) Si
(2) Si and CO_2
(3) Si, CO_2, and SiC admixture
(4) SiO, CO, and SiC admixture

11. Sodium carbonate, which is one of the most important products of the chemical industry, is prepared by the Solvay process based on the interaction of sodium chloride with ammonia and carbon dioxide. The reaction yields

(1) NH_4HCO_3
(2) $NaHCO_3$
(3) NH_4Cl
(4) $(NH_4)_2CO_3$

which is filtered off and then heated to produce calcined soda according to the reaction ....
12. Potash (potassium carbonate) is produced in industry by a variety of techniques:

(1) from wood ash
(2) by carbonization of caustic potash
(3) directly from potassium salts
(4) by the formate method

Potash manufacture described by the reaction equation $2KOH + CO_2 = K_2CO_3 + H_2O$ refers to the technique . . .
13. Boron has found extensive application in the current engineering. It is manufactured by reducing boron(III) oxide by the magnesium-reduced method:

$B_2O_3 + 3Mg = \ldots$

Boron(III) oxide is prepared by decomposing

(1) boranes
(2) boric acid
(3) borax
(4) calcium salts of polyboric acids

14. Sodium hydroxide (caustic soda) is used in a variety of the fields of industry. Its preparation is effected by various methods:

(1) electrolysis of a solution of common salt (iron cathodes and graphite anodes)
(2) electrolysis of a solution of common salt (mercury cathode)
(3) heating of sodium carbonate solution with milk of lime
(4) the ferrite method

An old method of NaOH preparation, which was known to alchemists, is .... The reaction equation reads ....

15. Superphosphate is prepared by treating the ground apatite concentrates or native phosphorites with sulphuric acid:

$$Ca_3(PO_4)_2 + 2H_2SO_4 = \dots$$

16. Double superphosphate, a fertilizer showing a higher phosphorus concentration than superphosphate, is manufactured by treating phosphorite with phosphoric acid according to the scheme:

$$Ca_3(PO_4)_2 + 4H_3PO_4 = \dots$$

17. Precipitate, a concentrated phosphorus fertilizer, is readily soluble in organic acids. It is prepared by neutralization of phosphoric acid with calcium hydroxide in the reaction

$$H_3PO_4 + Ca(OH)_2 = \dots$$

18. A valuable fertilizer can be prepared by phosphoric acid neutralization with ammonia. The fertilizer is

(1) saltpeter (3) bone flour
(2) ammophos (4) phosphate fertilizer

19. Neutralization of a 20% ammonia solution of a volume of 10 litres ($\rho \approx 1$ g/cm^3) with nitric acid yields ammonium nitrate of a mass of about (in kg)

(1) 2.1 (3) 9.4
(2) 4.2 (4) 18.8

20. In industry, hydrogen is commonly prepared from native methane. The method is based on steam-and-water and oxygen conversion of methane:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$
$$2CH_4 + O_2 \rightarrow 2CO + 4H_2$$

followed by the catalytic oxidation of CO with water vapour according to the scheme ... .

3.2 How Do We Obtain Metals!

"When we discuss problems of raw materials, the problem of metals soon becomes the main theme of our concern. Here it is quite pertinent to exclaim, Let's take care of the metals!"

Siegfrid Poller

1. Manufacture of metals from ores is the task of metallurgy. The metal preparation techniques underlie the following metallurgical processes:

(a) pyrometallurgy
(b) thermal reduction methods
(c) hydrometallurgy
(d) electrometallurgy

Examine the examples given below and indicate the type of the metallurgical process.

Metal preparation technique	*Process*
(1) Metal preparation by electrolysis	...
(2) Reduction of metals from their compounds by a metal that is more active chemically	...
(3) Manufacture of metals from ores by reduction reactions at high temperatures	...
(4) Preparation of metals from their salt solutions	...

2. Hydrogen-reduction method gives high-purity metals. This technique is used in the preparation of a metal in the reaction

(1) $ZnO + C = Zn + CO$
(2) $TiCl_4 + 2Mg = Ti + 2MgCl_2$
(3) $MoO_3 + 3H_2 = Mo + 3H_2O$
(4) $CuSO_4 + Fe = Cu + FeSO_4$

3. Copper or nickel refining by electrolysis is the metal preparation technique called

(1) thermal reduction
(2) electrometallurgy
(3) aluminothermy
(4) hydrogen-reduction

4. Spodumene $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$ is the most valuable mineral containing about 7% lithium. The final stage of lithium production is electrolysis of its chloride. Spodumene conversion to LiCl occurs in several stages. Write the reaction schemes for each stage.

Process stage	*Reaction scheme*
(1) Treatment of the ground mineral with sulphuric acid	...
(2) Leaching out of lithium sulphate with water and precipitation of carbonate	...
(3) Carbonate conversion into chloride	...
(4) Electrolytic decomposition of LiCl melt (in a mixture with KCl)	...

5. Which metal cannot be prepared in the pure form from its oxide by hydrogen-reduction?

(1) Tungsten
(2) Iron
(3) Calcium
(4) Molybdenum

6. In industry, metals are prepared from their oxides using these reducing agents: ....
7. Metallic potassium cannot be prepared by the method involving

(1) potassium displacement from melted KCl with sodium
(2) electrolysis of KCl-NaCl melt with the formation of sodium-potassium melt, and potassium separation by distillation
(3) KCl reduction on heating in vacuo by aluminium
(4) electrolysis of potassium chloride melt

8. Electrolysis of a sample of sodium chloride melt weighing 234 g yields metallic sodium of a mass of (in g):

(1) 23
(2) 46
(3) 69
(4) 92

9. Bauxite, cuprite, gypsum, dolomite, and pyrite are native minerals. Magnesium can be obtained from ....
10. In industry, high-purity magnesium can be prepared by the electrolytic decomposition of

(1) molten $Mg(OH)_2$
(2) seawater containing Mg^{2+}
(3) molten $MgCl_2$
(4) molten dolomite

11. Magnesium ranks second among the metallic elements that are constituents of the seawater. Its separation from the seawater is effected in several processes, which can be represented by the relevant reaction scheme.

Process	*Reaction scheme*
(1) Precipitation of Mg^{2+} as magnesium hydroxide with quick lime	...
(2) Treatment of the isolated precipitate with a mixture of HCl and H_2SO_4 solutions	...
(3) Separation of the obtained magnesium chloride solution from Ca^{2+} impurity precipitated as calcium sulphate	
(4) Evaporation of the magnesium chloride solution and electrolysis of the melt	...

12. Electrolysis of molten calcium chloride yields: at the cathode, ..., and at the anode, ...
13. Electrolysis of potassium hydroxide solution involving carbon electrodes resulted in the evolution of 500 cm^3 of a gas at the anode. The cathode reaction yielded

(1) potassium, 0.87 g (3) hydrogen, 500 cm^3
(2) potassium, 1.75 g (4) hydrogen, 1000 cm^3

14. Aluminium is manufactured by electrolysis of molten

(1) bauxite $Al_2O_3 \cdot H_2O$
(2) alumina Al_2O_3
(3) cryolite Na_3AlF_6
(4) Al_2O_3 in a molten bath of cryolite

15. Below are given the names and the compositions of aluminium ores. Write the chemical formulas for these ores reflecting their compositions.

Name of the ore	Mass percent		Chemical formula
	Al_2O_3	H_2O	
(1) Hydrargillite	65.3	34.7	...
(2) Diaspore	85.0	15.0	...

16. Electrolysis of 1 ton of Al_2O_3 can yield metallic aluminium of a mass of (in kg):

(1) 265 (3) 795
(2) 530 (4) 1000

17. Melting of aluminium in electrical furnaces requires cryolite, which can be synthesized by treating a mixture of 1 mole of $Al(OH)_3$ and 3 moles of NaOH with hydrofluoric acid. The reaction equation reads ... .
18. The most widespread minerals containing zinc are calamine (chemical formula, ...) and zinc blende (chemical formula, ...). Manufacture of zinc from these minerals is described by the reaction equations... .
19. Copper is prepared from the mineral malachite in the reactions ... and ... .
20. One of the methods by which copper is prepared from ore containing copper as copper(I) sulphide is this. The ore is first roasted in the air flow (the reaction ... occurs). Then the roasted ore is mixed with half as much amount of unroasted ore. The mixture obtained is calcined with no admission of air. The reaction equation reads ... .
21. Copper is manufactured from an ore containing the mineral chalcopyrite $CuFeS_2$. If the pyrometallurgical process occurs with a 100% yield, which mass (in g) of metallic copper can be prepared from 1 kg of the mineral?

(1) 173 (3) 519
(2) 346 (4) 692

The net reaction equation describing the pyrometallurgical process of copper preparation is ... .
22. Purification of metals can be effected by electrolysis. Which anode should be chosen from those given below for the preparation of pure copper by electrolysis of copper(II) chloride?

(1) Pt (3) Ni
(2) C (4) Cu

23. Complete reduction of copper(II) oxide powder of a mass of 79.5 g with hydrogen yielded metallic copper with the mass (in g)

(1) 32.75 (3) 63.5
(2) 39.75 (4) 79.5

24. Thermal reduction of a mixture of copper(II) oxide and iron(III) oxide weighing 31.9 g yielded 9 g of water. The mass percent of the metals in the mixture after the reduction was

(1) 22% Cu and 78% Fe
(2) 11% Cu and 89% Fe
(3) 50% Cu and 50% Fe
(4) 75% Cu and 25% Fe

25. Electrolysis of a copper sulphate solution yields at inert electrodes

(1) Cu, SO_2 (3) Cu, H_2
(2) Cu, O_2 (4) H_2, O_2

26. Write the chemical formulas of the iron ores listed below that reflect their essential composition:

Ore	*Formula*
(1) Limonite	...
(2) Hematite	...
(3) Magnetite	...
(4) Siderite	...

27. It is most advantageous to extract iron from

(1) hematite (3) limonite
(2) magnetite (4) siderite

28. The preparation of 1 ton of an alloy with a mass percent of iron equal to 95% requires this mass (in kg) of red iron ore containing iron(III) oxide (mass percent 78%, the rest—impurities):

(1) 950 (3) 1600
(2) 1357 (4) 1740

29. Iron is extracted from ores by reducing their oxides with coke and carbon(II) oxide in blast furnaces.

As a result, pig iron is formed which, in addition to iron, contains ... as impurities.

30. The chemistry of iron reduction in blast furnaces from iron(III) oxide can be represented as four major stages described by the following reaction equations:

Process stage	*Reaction equation*
(1) Formation of iron(II, III) oxide	
(2) Reduction of the latter to iron(II) oxide	
(3) Reduction with carbon(II) oxide to metallic iron	
(4) Reduction with coke to metallic iron	

31. On reduction of iron from an ore, admixtures contained in the ore may partially be reduced too. Complete the equations for the reduction of these substances:

(1) $SiO_2 + C \rightarrow \ldots$
(2) $MnO + C \rightarrow \ldots$
(3) $Ca_3(PO_4)_2 + C \rightarrow \ldots$

32. The initial ore contains sulphur as an admixture in the form of $CaSO_4$ or FeS_2. In the process of iron reduction, sulphur converts to

(1) SO_2 (3) CS_2
(2) H_2S (4) FeS

33. The gas that evolves from a blast furnace is called a blast furnace gas. It shows the following composition in volume percent: CO, 32.0; CO_2, 14.0; and N_2, 54.0. Combustion of 1 m^3 of this gas requires the following amount of air (in m^3):

(1) 0.16 (3) 0.8
(2) 0.32 (4) 1.6

34. The Bessemer process of steel production involves the oxidants ... and the reductants ....

35. When steel is produced by the open-hearth process, pig iron impurities are "burned out" by oxidizing silicon with iron(II) oxide in the reaction ....

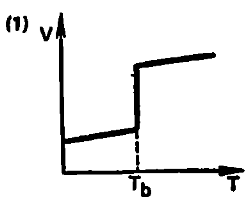
3.3 Modern Construction Materials—Glass and Concrete

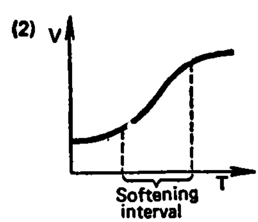
"To date the share of silicate articles in the total volume of industrial products is sufficiently great. Moreover, the diverse potentialities of processing and refining silicate raw materials have not yet been exhausted."

A. Hütter

1. Silica glasses are
   (a) crystalline bodies
   (b) amorphous bodies

   Which plot reflects the temperature dependence of their volume on heating?





2. Ordinary glass includes as its constituents
   (1) Na_2O, SiO_2
   (2) Na_2O, CaO, SiO_2
   (3) K_2O, CaO, SiO_2
   (4) Na_2O, CaO, SiO_2, B_2O_3, Al_2O_3
3. Ordinary glass is produced in the reaction ... .
4. In the manufacture of glass, sodium carbonate is occasionally replaced by a less expensive mixture of sodium sulphate and carbon. The relevant reaction occurs in compliance with the scheme ... .
5. Glassware is made from glass containing (in mass percent): SiO_2, 75.0; CaO, 9.0; and Na_2O, 16.0. This kind of glass possesses ... moles of Na_2O and ... moles of SiO_2 per mole of CaO. The chemical composition of this glass can be represented by the formula ... .

6. Fibre glass fabric is manufactured from glass containing (in mass percent):

Silica	54	Calcium oxide	16
Alumina	14	Magnesium oxide	4.0
Boron oxide	10	Sodium oxide	2.0

If we arrange these components in the order of increasing molar fractions, the chemical constituents of the glass can be represented by the formula ....

7. To manufacture coloured glass, the following ingredients are introduced into the initial charge: cobalt (II) oxide, manganese(II) oxide, iron(II) compounds, and chromium(III) oxide. What ingredients govern these colours of the glass?

Glass colour	*Ingredient*
(1) Blue	...
(2) Emerald-green	...
(3) Violet	...
(4) Green	...

8. Sodium carbonate, which is badly needed in glass production, practically does not occur in nature. It is synthesized in industry from sodium chloride. The first industrial method of soda manufacture from sodium chloride was developed by Leblanc in 1789. Table salt was first treated with concentrated sulphuric acid, then the product was mixed with limestone and carbon and smelted in a furnace. Sodium carbonate was extracted from the cooled melt by leaching with water. Thus, this process can be represented by three major stages described by the equations ....

9. Soda used in glass production can also be manufactured by the ammonia-soda process (Solvay process). Here the process proceeds also in three stages:

(1) concentrated sodium chloride solution is saturated with ammonia, and then carbon(IV) oxide is passed through the solution under a high pressure

(2) ammonium hydrocarbonate thus formed enters into an exchange reaction with sodium chloride

36. In Thomas converters, high-phosphorus pig irons are treated to convert phosphorus to slag. To this end, quick lime ... is added to the converter charge. Phosphorus removal is described by the reaction equation ....
37. Wrought iron contains carbon whose mass percent is

(1) 4-4.5
(2) about 1.7
(3) from 0.3 to 1.7
(4) up to 0.3

38. Pig iron production in a blast furnace requires about 180 tons of limestone per 1000 tons of the ore. If about 350 tons of slag is formed in the process, what is the mass percent of the impurity in the ore?

(1) 10
(2) 18
(3) 25
(4) 35

39. One of the approaches for obtaining high-purity metals is the synthesis of metal carbonyls followed by their decomposition. In the case of iron purification, these processes can be represented by the scheme:

$$\underset{\text{(unpurified)}}{Fe} + \ldots \xrightarrow{T} \ldots \xrightarrow{T} \underset{\text{(purified)}}{Fe} + \ldots$$

40. In powder metallurgy, iron powder is produced by decomposing iron pentacarbonyl. The mass (in kg) of iron pentacarbonyl needed to prepare 2 kg of iron powder is

(1) 7
(2) 3
(3) 5
(4) 1

41. Aluminothermy, which consists in the reduction of metals from their oxides by burning a mixture of these oxides with aluminium powder, was discovered in the end of the nineteenth century by the Russian chemist ....
42. Aluminothermy is used to produce metallic

(1) Mg
(2) Cu
(3) Cr
(4) K

43. Which pair of the substances listed below should be taken to produce chromium by aluminothermy?

(1) Cr, Al_2O_3
(2) Cr, Al
(3) Cr_2O_3, Al_2O_3
(4) Cr_2O_3, Al

44. The reaction equation describing chromium manufacture by aluminothermy reads ... .

45. To produce 39 g of chromium from its oxide by aluminothermy, take a sample of aluminium weighing (in g)

(1) 10.125
(2) 20.25
(3) 27
(4) 40.5

46. The most widespread ore used in the production of chromium is ... whose formula reads ... .

47. The mass percent of chromium in ferrochrome obtained by reducing chrome iron ore is

(1) 96
(2) 65
(3) 48
(4) 32

48. One of the industrial methods for the production of metallic calcium is roasting of calcium oxide with metallic aluminium in high vacuum. The theoretical expenditure of aluminium (in kg) for the production of 100 kg of calcium using this technique is

(1) 135
(2) 67.5
(3) 45
(4) 22.5

49. The naturally occurring mineral erythrite (cobalt bloom) $Co_3(AsO_4)_2 \cdot 8H_2O$ is the product of weathering of cobaltite (cobalt glance CoAsS) and arsenides of cobalt and nickel. Cobalt is produced from this ore. To obtain 1 kg of cobalt ... kg of the ore is needed (ignore the production losses).

50. Reduction of 1.82 g of vanadium oxide with metallic calcium yielded 1.02 g of pure vanadium. Vanadium oxide formula is ... and the reduction reaction equation reads ... .

51. Which method for metal production (or their purification) of those listed below is not effective in the manufacture of hyperpure metals?

(1) Zone refining of metals
(2) Vacuum remelting of metals
(3) Decomposition of volatile metal compounds
(4) Electrothermic reduction of metals

52. A 5 A electric current was passed through solutions of silver nitrate, copper(II) sulphate, and gold(III) chloride connected in series into a direct current circuit for 20 minutes. The mass (in g) of the metals deposited at the cathodes was

(1) Ag, 1; Cu, 1; Au, 1
(2) Ag, 3.35; Cu, 1; Au, 2
(3) Ag, 6.7; Cu, 2; Au, 4
(4) Ag, 6.7; Cu, 4; Au, 12

53. Titanium, which is the most valuable metal for modern technology, is produced from enriched titanium ores by treating them with a view to separating titanium dioxide TiO_2. The oxide is then transformed into titanium(IV) chloride with an aid of carbon and chlorine in the reaction .... .
Further, use is made of an industrial method for titanium manufacture developed in 1940, which was named:

(1) hydrogen-reduction
(2) magnesium-reduction
(3) electrolysis
(4) aluminothermy

The process occurs by the reaction ... .

54. The principal mineral that contains lead is ... (lead glance), PbS. Lead is produced in two steps: roasting according to the scheme ... and in the interaction with the product of the reaction between coke and oxygen ... .

55. Tinstone (the mineral ...) is the initial material for tin production by

(1) reduction with carbon
(2) magnesium-reduction
(3) electrolysis
(4) hydrogen-reduction

The reaction equation for the process reads ....

56. Enriched tungsten ores containing $CaWO_4$ or $FeWO_4$ convert to H_2WO_4 which is decomposed to tungsten(VI) oxide. At temperatures about 1000 °C tungsten(VI) oxide is reduced by hydrogen in the reaction ....

57. Name the metal among those listed below that occurs in the native state:

(1) Ca (3) Ga
(2) Mg (4) Ag

58. Manganese in the form of silicomanganese can be produced in the reaction:

(1) $MnO_2 + 2C \xrightarrow{T} Mn + 2CO$
(2) $MnO_2 + Si \rightarrow Mn + SiO_2$
(3) $3Mn_3O_4 + 8Al \rightarrow 9Mn + 4Al_2O_3$
(4) $2MnSO_4 + 2H_2O \xrightarrow{\text{electrolysis}} 2Mn + O_2\uparrow + 2H_2SO_4$

59. Roasting of the mineral cinnabar ... leads to mercury production according to the scheme ....

60. Gold extraction from an ore is effected by the cyanide method. Its essence is described by these reaction equations:

(1) $4Au + 8KCN + O_2 + 2H_2O = \ldots + 4KOH$
(2) $\ldots + Zn = K_2[Zn(CN)_4] + 2Au$

61. The first manual on metallurgy was published by the scientist

(1) P.P. Anosov
(2) I.P. Bardin
(3) M.V. Lomonosov
(4) D.K. Chernov

3.3 Modern Construction Materials—Glass and Concrete

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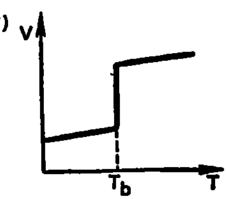
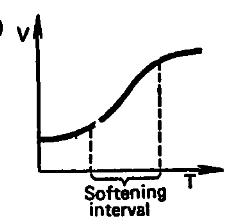


(2)


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(1) concentrated sodium chloride solution is saturated with ammonia, and then carbon(IV) oxide is passed through the solution under a high pressure
(2) ammonium hydrocarbonate thus formed enters into an exchange reaction with sodium chloride

(3) sodium hydrogen carbonate precipitate formed is filtered off and then calcined

Equations for these reactions read ....

10. Sodium hydroxide solutions are kept in plastic vessels rather than in glass ones, since glass contains ..., which is capable of reacting with NaOH according to the equation ....
11. Glass etching with hydrofluoric acid can be described by the equation ....
12. The glass that is used for preparing optical lenses and ornamental crystal glass is manufactured by replacing CaO in the charge for ordinary glass by

(1) CoO	(3) Mo_2O_3
(2) B_2O_3	(4) PbO

13. It is relatively recently that phototropic glasses have been created which are capable of getting cloudy and coloured when exposed to light and of recovering their initial state when placed in the conditions of low illumination. This glass contains a colloidal suspension in the form of AgCl or AgBr, sensitive to light, which decomposes them:

(1) reaction in the light is ...
(2) reaction in the dark is ...

14. Silica glass containing $Na_2B_4O_7$ or H_3BO_3 as admixtures shows high thermal and chemical stability. This glass is called ... and its constituents are (amounts in mass percent):

SiO_2	81	CaO	0.5
$Al_2O_3 + Fe_2O_3$	2	Na_2O	4.5
...	12		

15. Ordinary cement (or Portland cement) is widely used as a binder. It includes the following major components:

(1) $Ca(OH)_2$, SiO_2, H_2O
(2) $CaSO_4 \cdot O$, $5H_2O$, $CaSO_4$

(3) CaO, SiO_2, Al_2O_3
(4) $MgCl_2$, MgO

16. The major raw materials for the construction material industry are ..., ..., and .... Their essential composition can be expressed by the formulas ..., ..., and ....

17. To prepare cement, a finely ground mixture of limestone with sand and clay (and a small amount of iron(III) oxide as catalyst) is roasted in a rotary kiln. The resulting product is a sintered granular mass, which is called .... It is a semifinished product which is ground in a ball mill to obtain the final product. The roasting process can be represented by the reaction ....

18. The major component of aluminous cement is calcium aluminate $Ca(AlO_2)_2$. Seizing of this cement is primarily due to the hydration of metaaluminate and simultaneous separation of aluminium hydroxide according to the reaction equation ....

19. The mineral composition of Portland cement primarily includes the compounds ..., ..., ..., and a small amount of .... Cement seizing is determined by the reactions ....

20. The most valuable properties of cement are:

(1) strength
(2) insolubility in water
(3) resistance to cold
(4) sound-absorbing capacity
(5) low heat conductivity
(6) electrical conductivity

The statement ... is wrong.

21. The technology of cement manufacture includes three principal stages:

$\ldots \rightarrow \ldots \rightarrow \ldots \rightarrow$ Cement

Decipher the scheme using the descriptions of the three stages of this technological process given below:

(1) roasting of limestone-clay rock or a clay-limestone mixture

(2) grinding of clinker in ball mills into fine powder
(3) preparation of a raw mixture

22. Magnesian cement, which is stable to the action of acids and alkalis, is prepared from a mixture of concentrated $MgCl_2$ solution (approximately 30%) and preliminarily ignited MgO. Solidification of this cement results in an inorganic polymer of the composition ....
23. A mixture of cement, sand, and gravel is called ..., and the material produced by embedding steel rods is called ....
24. Concrete employed in fortification and winter-time construction is prepared from

(1) aluminous cement
(2) magnesian cement
(3) Portland cement
(4) pozzuolan cement

25. Concretes are mixtures of cement, native or synthesized aggregate showing different-size particles, and water. Concretes can be classified by

(a) density
(b) composition (kind of aggregate)
(c) treatment technique
(d) employment

Indicate the classification principle (*a* through *d*) for each kind of concrete listed below.

Kind of concrete	*Classification principle*
(1) Facing, road-building, for protection against radiation	...
(2) With quartz sand, compression-moulded, vibrated, poured	...
(3) Light-aggregate, heavy-aggregate, very heavy-aggregate	...
(4) With a light aggregate (foam concrete, pumice concrete), with quartz sand, gravel, breeze concrete	...

26. Reinforced concrete, which is the primary constructional material in civil engineering, exhibits these properties:

(1) high compressive strength and tensile strength
(2) good mouldability
(3) high insulation parameters
(4) cheapness

The property ... of reinforced concrete is used in the production of thin-walled large-diameter cupolas.

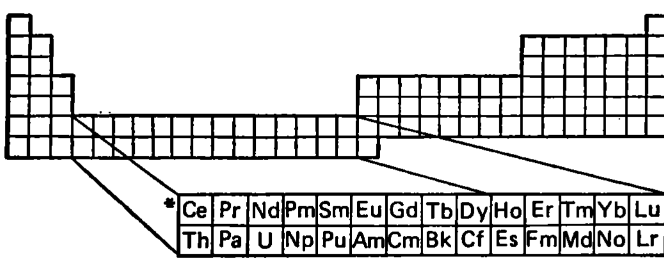
Chapter **4**

Multiple Tests

"What region of mechanical arts does not need chemical knowledge? ... If Mankind had to choose only three sciences from amongst all the sciences and namely those to fit our requirements, mechanics, natural history, and chemistry should have been favoured."

Denis Didrot

1. The (*) row of the elements shown in the figure is called
(I) actinides (II) lanthanides



All the elements of this family can be referred to

(1) *s* elements (3) *d* elements
(2) *p* elements (4) *f* elements

In the free state, they are typical ... and exhibit this most characteristic oxidation state in compounds:

(a) + 1 (c) + 3
(b) + 2 (d) + 4

With progression to higher nuclear charge, the atomic size of these elements

(a′) increases
(b′) decreases

(c′) remains unchanged
(d′) increases and then decreases

This phenomenon is called ....

2. The mass percent of oxygen in an oxide of a certain metal is 22.55%, and in the other oxide, 50.48%. The relative atomic mass of the metal is ..., the metal is .... The formula of the first oxide reads ... and that of the second, ...

3. A sample of soda crystals weighing 1.287 g has reacted with excess hydrochloric acid to evolve 100.8 cm^3 of a gas (at STP). The formula of the crystal hydrate is

(1) $Na_2CO_3 \cdot 10H_2O$ (3) $Na_2CO_3 \cdot H_2O$
(2) $Na_2CO_3 \cdot 7H_2O$ (4) Na_2CO_3

4. The ancient Tadjik philosopher-scientist, the famous physician, who lived at the end of the first and the beginning of the second millennium. He composed *Canon of Medicine*, which is among the most famous books in the history of medicine; he was an adversary to alchemistry and astrology. His name is ....

5. Which gas of those given below is the heaviest?

(1) Xe (3) NH_3
(2) O_3 (4) WF_6

6. Which of these gases is most readily soluble in water?

(1) Ammonia (3) Carbon dioxide
(2) Hydrogen sulphide (4) Nitrogen

7. Which of the substances presented below is a poison for the human organism even in small doses?

(1) $MgSO_4 \cdot 7H_2O$ (3) $Na_2SO_4 \cdot 10H_2O$
(2) $HgCl_2$ (4) $NaHCO_3$

8. Hydrogen chloride impurity is removed from hydrogen most effectively by

(1) H_2SO_4 (conc.) (3) CuO (solid)
(2) H_2O (liquid) (4) KOH (sln)

9. Which compound of those listed below is most expedient to be used as a potassium fertilizer (neglect the cost of the compounds)?

(1) KCl (3) $KHSO_4$
(2) K_2SO_4 (4) KNO_3

10. Which mass of a substance corresponds to the Avogadro number of molecules?

(1) 4.4 g CO_2 (3) 36 g H_2O
(2) 17 g NH_3 (4) 49 g H_2SO_4

11. The values of the standard potentials for some oxidation-reduction pairs are

$2S_2O_3^{2-}/S_4O_6^{2-}$ $E_1^\circ = 0.17$ V
$2I^-/I_2$ $E_2^\circ = 0.53$ V
$2SO_4^{2-}/S_2O_8^{2-}$ $E_3^\circ = 2.05$ V

Arrange the oxidizing agents from these pairs in the order of increasing oxidative property: ... < ... < .... Show the direction of the reactions written below:

(1) $2I^- + S_4O_6^{2-} \ldots I_2 + 2S_2O_3^{2-}$
(2) $2I^- + S_2O_8^{2-} \ldots I_2 + 2SO_4^{2-}$
(3) $2S_2O_3^{2-} + S_2O_8^{2-} \ldots S_4O_6^{2-} + 2SO_4^{2-}$

12. A mixture of sand and iron filings can be separated by

(1) filtering (3) evaporation
(2) using a magnet (4) settling

One of the components of this mixture is readily soluble in

(a) water
(b) HCl solution
(c) benzene
(d) carbon tetrachloride

to form a compound whose chemical formula reads ....

13. Carbon(II) oxide forms with nickel a volatile carbonyl of the ... composition. Its boiling point is 43 °C. The bond in nickel carbonyl is formed involving sp^3 orbitals of the nickel atom. Based on this

information, confirm the validity of the following statements adding the relevant comments:

(1) the nickel carbonyl molecule has a tetrahedral structure, because ...
(2) nickel carbonyl molecules are attracted by van der Waals' forces, which is indicated by ...
(3) nickel carbonyl in the liquid state does not conduct electric current, since ...
(4) nickel carbonyl is insoluble in water; this can be attributed to the fact that ...

14. Sodium carbonate melts at 890 °C without decomposition, whereas silver carbonate starts decomposing at 220 °C. This difference in their properties can be due to

(1) the strong deforming action of Ag^+ (as a *d* element) as compared with K^+ (noble gas shell)
(2) the fact that Ag finds itself in Group IB and K, in Group IA of the periodic table
(3) the fact that K is a much more active metal than Ag.
(4) the fact that the ionic radius of Ag^+ is less than the ionic radius of K^+

15. Write the formulas of the hydrogen compounds of calcium, tellurium, germanium, and bismuth . ... exhibits an ionic character.

16. The oxides of which element can have compositions other than stoichiometric ones?

(1) Hydrogen
(2) Sulphur(IV)
(3) Sodium
(4) Carbon(IV)

The oxide compositions are always stoichiometric for

(a) iron(II)
(b) sulphur(VI)
(c) praseodymium
(d) potassium

17. A student has found the mass of a sample of some substance to be 38.81 g. Actually, the sample mass was 38.42 g. Calculate the inaccuracy (in %) of the determination:

(1) 0.0104 (3) 0.400
(2) 0.104 (4) 1.04

18. Ion-exchange resins are used to purify water to prepare

(1) distilled water
(2) decalcined water
(3) water showing a high OH^--ion concentration

19. In recent years, the moon ground samples have been analysed. A great similarity between the compositions of the earth crust and the moon surface has been revealed. Nevertheless, the concentrations of certain oxides in basalt ores of the moon substance substantially differ from the composition of the earth rocks (being both, higher and lower). Which sequence of oxides given below substantially distinguishes the earth ground from the moon one by their concentrations in the rocks?

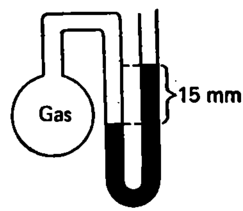
(1) CaO, SiO_2, MgO (3) TiO_2, SiO_2, MgO
(2) TiO_2, FeO, Na_2O (4) Na_2O, SiO_2, CaO

20. Samples of substances were placed in seven evacuated quartz ampoules of equal capacity connected with pressure gauges and then heated to a certain constant temperature. The pressure set in the am-

Run	Amounts of substances (in moles) in the ampoules prior and after the experiment				Pressure, kPa
	$FeCO_3$	FeO	$MgCO_3$	MgO	
(1)	0.1	—	—	—	4254.6
(2)	0.2	—	—	—	4254.6
(3)	0.1	0.1	—	—	4254.6
(4)	—	—	0.1	—	3.04×10^{-1}
(5)	—	—	0.2	—	3.04×10^{-1}
(6)	—	—	0.1	0.1	3.04×10^{-1}
(7)	0.1	0.1	0.1	0.1	
After run (7)	...	...	...	...	...

poules was recorded, the ampoules slowly cooled, and the contents determined. The amounts of substances prior and after the experiment remain unchanged in six ampoules. Account for the results of the six runs (see the table) and give the data for the seventh run.

21. A pressure gauge with an open end (see the figure) is connected to a flask containing a gas and is filled with mercury. The difference between the levels is 15 mm. Calculate the pressure (in kPa) of the gas in the flask, if the atmospheric pressure is 101.3 kPa (1 mm Hg = 0.1333 kPa):



(1) 2.0
(2) 99.3
(3) 101.3
(4) 103.3

22. On heating, ammonium chloride dissociates into gaseous products according to the equation .... Three sealed ampoules of a 1-litre capacity contain 0.2 mole (*A*), 1 mole (*B*), and 2 moles (*C*) of ammonium chloride.
The ampoules were heated to the temperature at which the pressure in the ampoule *A* became 33.43 kPa. The pressure in the ampoule *B* changed to ... kPa and that in the ampoule *C*, ... kPa.

23. Equations for the reactions of thermal decomposition of ammonium salts can be written in this way:

(1) $NH_4ClO_4 \xrightarrow{T} \ldots$
(2) $(NH_4)_2SO_4 \xrightarrow{T} \ldots$
(3) $(NH_4)_2S_2O_8 \xrightarrow{T} \ldots$
(4) $NH_4NO_2 \xrightarrow{T} \ldots$

24. A sample of sodium-aluminium amalgam weighing 5.48 g was treated with excess hydrochloric acid. The undissolved substance was filtered off and weighed.

Its mass was 4.02 g. The amalgam composition in mass percent was:

(1) Na, 16.8%; Al, 9.8%; Hg, 73.3%
(2) Na, 10.5%; Al, 16.1%; Hg, 73.3%
(3) the problem includes superfluous data, i.e. the mass of the undissolved substance 4.02 g, which is not used when solving the problem
(4) the problem lacks the necessary condition to solve it—the volume of evolved hydrogen and the conditions under which it was measured

25. Compare three salts of the $M_2S_2O_x$ composition, where x denotes three small integers, and M is an alkali metal. Consider these statements:

(1) the anion contains the O—O bond
(2) the anion contains the S—S bond
(3) the anion contains the S—O—S bond
(4) the salt forms on thermal decomposition of hydrosulphate
(5) the salt forms on anode oxidation of hydrosulphate
(6) the salt forms in the interaction of an aqueous sulphite solution with sulphur
(7) an aqueous solution of the salt dissolves silver bromide
(8) neutralization of an aqueous solution of the salt with the MOH hydroxide yields the M_2SO_4 sulphate
(9) the salt in an aqueous solution oxidizes Mn(II) to permanganate

and choose those relating to the given salt. In the formulas of the salts write the subscript to the oxygen atom.

Salt formula	*Statement*
M_2S_2O. . .	. . .
M_2S_2O. . .	. . .
M_2S_2O. . .	. . .

The reaction equations ... relate to the statements (4) through (9).

Chapter 5 Try Yourself to Make a Chemistry Test. How Can You Do It?

Test—an examination to determine factual knowledge or mental proficiency.

Webster's Dictionary of the English Language

We have described the notion 'test' in the introduction. This is a standardized assignment. The way it is performed by a student testifies to his certain capacities, as well as to the scope of his knowledge, know-how, and skill. Standardized tests that are constructed using a definite scope of the curriculum material (e.g. inorganic chemistry) are commonly called *progress tests*. They are employed for evaluating the level a student has reached in mastering the curriculum programme and acquiring some skill. They allow *measuring* this know-how, capacities, and skill of a student.

Written tests are generally constructed with a view of getting the student's answer in two ways: (1) *independent formulation* (*construction*) *of an answer and* (2) *selection of the correct answer*.

Independent formulation of an answer by a student may occasionally cause not an unbiased evaluation of the answer—the more freedom the student possesses when he writes an answer, the more diverse may be the teacher's evaluation of the answer. Therefore the answer should be planned so as to be unambiguous, brief, and clear.

The selection approach can be used in working out a test in the following two cases:

(1) when only such situations are presented for choosing that can be observed in the field under study and should be mastered by the students, and it is crucial that the student must know the number of the major types of the situations offered to be chosen;

(2) when none of the situations suggested for selection forms the subject under study (for example, number and letter symbolism that characterizes only the given data, specific conditions of the problem, the numerical conditions for the problem, etc.).

Both cases are evidently quite contradictory.

Multiple tests can also be used. They presuppose a free formulation of the answer as well as its selection from the alternative ones suggested by the teacher.

Regarding their subject matter, assignments can be classed into *subject* (which check the student's know-how in a particular subject); *logical* (with a complete set of conditions, with an incomplete set of conditions, with a complete set of conditions plus a superfluous one, and with an incomplete set of conditions plus a superfluous one); and *psychological*, i.e. those which are constructed using different correlations between descriptive and conceptional signs presented in the conditions of the problem and in relevant drawings and figures (for correlation). Assignments can be both *direct* and *reverse*.

The control itself via tests should meet the demands of the two types of validity (*validity* is a notion indicating what is measured by the test and how efficient it is):

(1) subject (i.e. knowledge of a particular subject matter);

(2) functional (i.e. types of cognitive activity: placing coefficients in equations, performing standard calculations, applying general regularities to specific phenomena).

Consequently, the test also must be in compliance both with the subject under study and with the tasks of teaching.

We now illustrate all these considerations using some simple examples.

Example 1. Lithium properties are known to differ substantially from those of the other alkali metals. For instance, LiF, Li_2CO_3, and Li_3PO_4 are sparingly soluble in water, lithium hydroxide is very sparingly soluble in water as compared with the other alkali metal hydroxides (12 g LiOH per 100 g H_2O at 20 °C).

The test may be formulated in this manner:

Which of the hydroxides of alkali metals is only sparingly soluble in water?

(1) LiOH (3) KOH
(2) NaOH (4) RbOH

The alternative answers include hydroxides known to students.

It is preferable to put the sentence in the affirmative.

An alkali metal hydroxide that is the least soluble in water is

(1) LiOH (3) KOH
(2) NaOH (4) RbOH

Example 2. In the laboratory, silicon is obtained by reducing quartz sand with magnesium: $SiO_2 + Mg \rightarrow Si + MgO$.

If we take equal samples of SiO_2 and Mg (for example, weighing 3 g each), the reaction will yield two products—Si and MgO—and when the reaction is complete, the mixture will also contain the initial reactant that has been taken in excess. Thus, we have at least three variants for an answer: Si and MgO; Si, MgO, and Mg; and Si, MgO, and SiO_2. Moreover, it should be borne in mind that the numerical answers can be different depending on whether the student has balanced the reaction scheme and obtained the reaction equation $SiO_2 + 2Mg = Si + 2MgO$ or not.

The correct solution: $M_r(SiO_2) = 60$; $A_r(Mg) = 24$; $A_r(Si) = 28$; $M_r(MgO) = 40$. Hence, SiO_2 sample weighing 3 g corresponds to 0.05 mole of the substance, and Mg sample weighing 3 g corresponds to 0.125 mole. An amount of 0.05 mole of SiO_2 is spent completely if 2×0.05 mole of Mg, i.e. 0.1 mole of Mg, react with it. Consequently Mg is in excess ($0.125 - 0.1 = 0.025$ mole).

On completion of the reaction the mixture will contain:

Si, 0.05 mole or 0.05×28 g $= 1.4$ g
MgO, 0.05×2 mole or 0.1×40 g $= 4.0$ g
Mg, 0.025 mole or 0.025×24 g $= 0.6$ g

12—01096

Erroneous variants of the solution:

A. The reaction scheme is not balanced; hence the mixture contains

Si, 0.05 mole, i.e. 1.4 g
MgO, 0.05 mole, i.e. 2.0 g
Mg, 0.125—0.05 = 0.075 (mole), i.e. 4.5 g

B. The reaction scheme is balanced, but the excess Mg is neglected (calculation in terms of SiO_2). Then the mixture contains:

Si, 0.05 mole, i.e. 1.4 g
MgO, 0.05 mole, i.e. 2 g

C. The reaction scheme is balanced but the excess Mg (calculation in terms of Mg) is disregarded. The mixture contains:

Si, 0.125 mole, i.e. 3.5 g
MgO, 0.125 mole, i.e. 5 g

Other erroneous variants are also possible, which are less typical but nonetheless feasible.

We now formulate the question for the test.

Samples of powdered SiO_2 and Mg weighing 3 g each react on heating according to the scheme: $SiO_2 + Mg \rightarrow Si + MgO$. On completion of the reaction the mixture contains (in g):

(1) Si, 1.4; MgO, 2.0
(2) Si, 3.5; MgO, 5.0
(3) Si, 1.4; MgO, 4.0; Mg, 0.6
(4) Si, 1.4; MgO, 2.0; Mg, 4.5

Selection answers may contain only symbols for elements and compounds, but in this case, we will have only three alternative answers:

(1) S, Mg
(2) Si, SiO_2, MgO
(3) Si, Mg, MgO

A fourth alternative answer (reasonable, not absurd) is impossible to formulate.

Based on the above problem a multiple test can also be devised, which will presuppose independent and selection answers. For example:

Interaction between powdered SiO_2 and Mg of a mass of 3 g each on heating in compliance with the reaction equation ... leads to the formation of a mixture of these products:

and then given are either numerical answers or answers in the form of the symbols and formulas of the elements and compounds.

* * *

Now, when you have read this brief guide to constructing tests and have considered the tests in this book you'll manage to independently design a written control test of your own.

Try to do this, and you'll see whether you have mastered the subject matter for which you have constructed the test. Don't grudge your time for this!

Answers and Explanations to the Tests

Section 1.1

1. Eka-boron (scandium), eka-aluminium (gallium), eka-silicon (germanium).
2. Beryllium. Atomic mass for beryllium was found to be 13.8; consequently, it was placed between carbon and nitrogen in the periodic table of the elements. Mendeleev believed in the validity of the regularity discovered by him and included beryllium in Group II of the periodic table insisting on its mass to be 9.
3. Gallium (Ga); the French chemist Lecoq de Boisbaudran. The discoverer of gallium was wrong in determining its density as 4.7 g/cm^3. Mendeleev believed that the density of gallium ("eka-aluminium" whose density he predicted five years earlier) must be higher, approximately 5.9-6.0 g/cm^3, which was borne out later on.
4. Noble gases, lanthanides, and actinides.
5. (1). Isotopes are atoms having the same number of protons but different number of neutrons.
6. (1) Si, (2) Cr, (3) Yb.
7. (4).
8. (1). The relative mass of an element is the ratio of its atomic mass to 1/12 mass of carbon-12 isotope.
9. (1). Electronegativity is the relative ability of an atom or group of atoms to attract electrons to itself.
10. (1). Among the atoms of the elements given, a sodium atom exhibits the lowest value of the ionization energy (i.e. the amount of energy needed to remove an electron from an atom or molecule to an infinite distance).
11. (1).
12. (4). Indium is named from the blue (indigo coloration) line of its spectrum; silicon, from Latin *silex* (silica); radium, from Latin *radius* (beam); ruthenium, from late Latin *Ruthenia* (Russia); the element was

discovered in 1844 in Russia by K. Klaus, Professor of Kazan University.

13. (3). Element 95 is named in honour of America.

14. Germanium (element); Germany (country).

15. (1).

16. (3).

17. (3). All the four *d* elements (Cr, Y, W, and Hg) are transition elements.

18. (3).

19. (4).

20. (2).

21. (1).

22. $^{254}_{99}Es + ^{4}_{2}He \rightarrow ^{258}_{101}Md$.

Glenn Theodore Seaborg (b. 1912). An American physicist and nuclear chemist, member of the National Academy of Sciences of the USA (since 1948). He is best known for his work on isolating and identifying transuranium elements. He became Professor of chemistry at Berkeley in 1945 and is now Chairman of the U.S. Atomic Energy Commission. He has put forward the actinide theory, developed the superfine methods for studying the properties of counted atoms of radioactive actinides. Has discovered the phenomenon of "fission" bombardment of nuclei, developed the theory of predicting the properties of the isotopes still undiscovered. President of the American Chemical Society (1976). Foreign member of the USSR Academy of Sciences (1971). Nobel Prize winner (1951) for the discovery in the chemistry of transuranium elements (in cooperation with E.M. McMillan).

23. Kurchatovium;

$$^{242}_{94}Pu + ^{22}_{10}Ne \rightarrow ^{260}_{104}Ku + 4^{1}_{0}n.$$

Kurchatov Igor Vasilievich (1903-1960). Soviet physicist, Academician (1943). Scientific work in the field of physics of dielectrics and semiconductors, physics of atomic nucleus. Discovered nuclear isomerism for the synthetic radioactive

isotope bromine-80. Investigated nuclear reactions initiated by fast and slow neutrons. He supervised the construction of a cyclotrone (1939), the most efficient in Europe of that time and the first Soviet atomic reactor (1946). Participated in the working out of the atomic (1949) and hydrogen (1953) bombs, the first in the world industrial atomic power station (1954). Lenin Prize laureate (1957). Four times holder of the State Prize of the USSR (1942, 1949, 1951, and 1954). The title of Hero of Socialist Labour has been conferred on him three times. The Institute of Atomic Energy bears his name. The element kurchatovium is named in his honour.

24. (1). The real mass of each individual atom is constant disregarding which arbitrary unit is used for its measurement. A mole of a substance contains an equal number of particles (6.02×10^{23}). Hence, a mass constant for a given substance corresponds to one mole.

25. (4). In the subgroup, the atomic size (and its radius) increases with increasing atomic number of an element.

26. (1). Group VIA elements (O, S, Se, and Te) are arranged in the order of increasing atomic number; the atomic size of the elements also increases.

27. (2). In the subgroup, metallic properties of an element increase with increasing atomic number.

28. (1). In the subgroup, non-metallic properties weaken with increasing atomic number of an element.

29. (3). The elements P and As are in the same subgroup.

30. (2). The elements Ra and Ba are in the same subgroup.

31. (3). Lanthanum is a Group III element in the periodic table of the elements; its electronic formula is $[Xe]5d^16s^2$; the most typical oxidation state of +3, which is also characteristic of lanthanides.

32. (2). Photoelectric effect is the liberation of electrons of a solid (or a liquid) by electromagnetic radiation incident on a substance, in particular, electron emission by light. Group I *s* elements, i.e. alkali metals, show the lowest values of ionization energy (the amount of energy needed to detach an electron from an unexcited atom).
33. (3).
34. (2). LiOH is substantially less readily soluble and a weaker hydroxide as compared with those of the other Group IA *s* elements; the basic properties of the hydroxide in the subgroup increase with increasing atomic mass; in aqueous solutions, NaOH, KOH, RbOH, and CsOH are almost completely ionized and are the strongest bases (alkalis).
35. $GeSe_2$ (for example, by analogy with CO_2).
36. (3). J. Priestley discovered oxygen in 1774. It is notable that the Swedish chemist C. Scheele, independently from Priestley, discovered oxygen somewhat earlier, but he reported his evidence on the "igneous air" only in 1777.
37. (3).
38. (1). An increase in the boiling (and melting) points of the simple substances in the series F—Cl—Br—I is due to the fact that halogens in the solid state form a molecular crystal lattice rather than an atomic one, and light halogens are much more difficult to transform into the liquid and solid state than heavy ones. This, in turn, is associated with the fact that molecular sizes of the light halogens are much smaller and therefore, on their compression, the repulsion forces will be higher. The intermolecular repulsion forces increase when passing from heavy to light halogens, which can be attributed to the difference in the electronic structures of the halogen atoms.
    Note also that the energy of van der Waals repulsion rapidly decreases with increasing interatomic distances and at high values of this distance it becomes extremely low.
39. (3). The elements F and Cl are found at the top of Group VIIA in the periodic table.

40. (4). The electronic structure of the atom: $[Ne]3s^23p^5$.
41. (1). The electronic structure of the atom: $[He]2s^22p^1$; most commonly it exhibits the oxidation state of $+3$; forms weak boric acid H_3BO_3.
42. $NaCl$, $MgCl_2$, $AlCl_3$, Na_2S, MgS, Al_2S_3.
43. (4). The electronic structure of the atom: $[Ar]4s^1$.
44. Henry Cavendish, the British chemist and physicist. Produced pure hydrogen in 1766 by treating zinc with sulphuric acid.
45. (2). $A_r(E) = 0.875 \times 4A_r(H)/0.125 = 28$, i.e. the unknown element is silicon.
46. (2). GeO_2 and GeH_4.
47. (3). Among the non-metals listed in the problem, the most reactive is chlorine, and among the metals, sodium.
48. (2). The character of the oxides of the third period elements changes from basic to acidic with increasing atomic number of an element; the series given in the problem shows the reverse tendency.

49.

(1)	N_2O_5	HNO_3	Nitric acid
(2)	P_2O_5	H_3PO_4	Phosphoric acid
(3)	As_2O_5	H_3AsO_4	Arsenic acid
(4)	Sb_2O_5	H_3SbO_4	Antimonic acid

50.

(1)	CaH_2	CaO	$Ca(OH)_2$
(2)	H_2S	SO_3	H_2SO_4
(3)	LiH	Li_2O	$LiOH$
(4)	CH_4	CO_2	H_2CO_3

51. C, Ge, and Si for both cases.

52.

(1)	ZnO	$Zn(OH)_2$	Amphoteric
(2)	Cu_2O	$CuOH$	Basic
(3)	P_2O_5	H_3PO_4	Acidic
(4)	SnO_2	$SnO_2 \cdot H_2O$	Amphoteric

53.

(1) SrO	(4) CrO_3
(2) PbO_2	(5) SO_3
(3) Mn_2O_7	(6) Cl_2O_7

54. H_2Se, SeO_3, H_2SeO_4; (1) strong acid.

55. (2). Hydrogen compound: H_2E; $A_r(E) = 97.53 \times 2A_r(H)/2.47 = 78.97$, i.e. the unknown element is selenium.

56. (1) $3Ca + 2P = Ca_3P_2$;
(2) $Rb_2O + SeO_3 = Rb_2SeO_4$;
(3) $Be(OH)_2 + 2CsOH = Cs_2BeO_2 + 2H_2O$;
(4) $Sr(OH)_2 + CrO_3 = SrCrO_4 + H_2O$;
(5) $H_2Se + Mg = MgSe + H_2$.

57. (1).
Mole percent in the Earth's crust, %:

Al	Ti	Mo	W
6.6	0.25	6×10^{-5}	1×10^{-5}

58. (2). Hydrogen is the most widespread element of the cosmos; it makes up more than 70% of the mass of the Sun and the stars and constitutes the major part of the gases of the interstellar space and nebulae.
59. Argon.
60. 1969.

Section 1.2.

1. Proton (p), electron ($\bar{e}$), and neutron (n).
2. Atomic number of an element; $_6C$.
3. Mass number; ^{14}C.

4.

(1)	$6p$	$7n$	$6\bar{e}$
(2)	$25p$	$30n$	$25\bar{e}$
(3)	$42p$	$55n$	$42\bar{e}$

5. (4).
6. (1).
7. (4). $11p$ and $10\bar{e}$.
8. (1). Carbon, oxygen, and phosphorus.
9. (4).
10. (3). Element $^{27}_{13}Al$ has three valence electrons and belongs to Group III of the periodic table.
11. (3). The O^{-2} ion has a completely occupied outermost shell: $8\bar{e}$.

12. (1). The Te^{2-} ion has an electronic configuration similar to that of xenone.
13. (4).
14. (2). The *s* orbital of any electronic level can accommodate 2 electrons as a maximum.
15. (3). The *p* sublevel can accommodate 6 electrons at most.
16. (3). The *d* sublevel can accommodate 10 electrons as a maximum.
17. (1). This electronic configuration belongs to the potassium atom in the ground (unexcited) state.
18. (3).
19. (3). The three particles have 10 electrons each.
20. (2). $6\bar{e}$ on $3d$ orbitals: $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$; $2\bar{e}$— paired and $4\bar{e}$—unpaired.
21. (3).
22. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^{10} 6s^1$.
23. (2).
24. (3), (6) ground;
(1), (5) excited;
(2), (4) forbidden.
25. (3).
26.

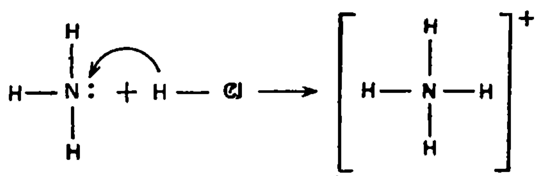
	(I)	(II)
(1)	Ion	Ground
(2)	Neutral atom	Excited
(3)	Neutral atom	Ground
(4)	Ion	Ground

27. (1). The electronic configuration of the Ca^{2+} ion is similar to that of argon.
28. (2); in the case (1) the first Hund's rule is violated.
29. $Na^+ < F^- < O^{2-} < Ne$.
30. (1) Boron, B (3) Fluorine, F
(2) Carbon, C (4) Sodium, Na
31. (2). The particles Cl^-, K^+, and Ca^{2+} have an electronic configuration of [Ar]; the ionic size decreases with increasing nuclear charge; among the four particles

Mg^{2+} has the smallest size. Thus, the ionic radius increases in the sequence:

$Mg^{2+} < Ca^{2+} < K^{+} < Cl^{-}$.

32. (4).
33. (1) $3d^3$ (4) $3s^2p^6$
(2) $3s^2p^6$ (5) $3s^2p^6$
(3) $3d^{10}$ (6) $6s^24f^{14}5d^{10}$
34. (4).
35. Ca^{2+}.
36. (3).
37. Decreases.
38. (2).
39. (1) $[Ar]3d^5$ MnO
(2) $[Ar]3d^3$ MnO_2
(3) $[Ar]$ Mn_2O_7
40. (2). Ionization energy, see 1.1, Problem 10.
41. (4).
42. (2).
43. (4). The ionization energy for magnesium is higher than that for sodium, since it is also spent in addition for unpairing $2s$ electrons. This absorption of energy is in compliance with the well-known Hund's rules. Aluminium shows a lower ionization energy than magnesium, since the detached p electron is screened from the nucleus by the s electron pair.
44. (1) calcium (K, 0.5 eV; Ca, —1.93 eV);
(2) chlorine (S, 2.07 eV; Cl, 3.6 eV);
(3) hydrogen (H, 0.75 eV; Li, 0.59 eV).
A conclusion as to the electron affinity can be drawn either after analysing the atomic structure of the pairs of elements or by considering the positions of the elements in the periodic table (comparing the atomic radii).
45. $H < S < Cl < O < F$.
46. (1).
47. (2).
48. (4).
49. (3).

50. (4).
51. (2). The electronic structure of both particles (Li^+ and H^-) is $1s^2$. The hydrogen nucleus has the charge of $+1$, that of lithium, $+3$; consequently, the electrons of the lithium ion will be attracted more strongly. Therefore the size of the lithium ion will be smaller as compared with that of the hydrogen ion. Indeed, the ionic radius of hydrogen is 0.136 nm, and that of lithium, 0.068 nm.
52. (3).
53. (4). The positively charged nuclei of the helium atom (^4_2He).
54. (4).
55. (3).
56. (2).
57. (1).
58. 79; 118; 79.
59. (2).
60. CCl_4, CH_4, CO_2, BeH_2, BCl_3, CS_2, and others.
61. (4).
62. (2).
63. H_2O, H_2S.
64. CsH. Can be attributed to the greater difference in the electronegativities of cesium and hydrogen atoms.
65. (3).
66. (2); 

67. (1).
68. Covalent character of the bond increases

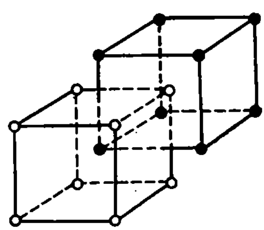
$\longrightarrow$

LiF, BeF_2, BF_3, CF_4, NF_3, OF_2, F_2

$\longrightarrow$

Ionic character of the bond decreases
69. (3).
70. (1).
71. (4).

72. *sp*. The CS_2 molecule is linear, non-polar due to the symmetric structure.
73. BeH_2; (1); (a). The beryllium hydride molecule has a bond angle equal to 180 °C.
74. (2); (b). In the trigonal structure of the BF_3 molecule the bond angle equals 120 °C, the molecule is non-polar due to its symmetrical structure.
75. (2).
76. (3). The half-life is the time interval required for one-half of any quantity of a substance to undergo radioactive decay.
77. (3).
78. (1). Drawing of the second elementary cell from the element B atoms allows defining the formula of the crystalline substance—AB.



79. (1) Molecular (4) Atomic
(2) Ionic (5) Ionic
(3) Molecular (6) Molecular

80. (4).
81. (1). Diffusion of gases is characterized by the rate of molecular motion. It is known from the kinetic theory that the rate of molecular motion can be defined by the root-mean-square rate value v, which is the square root of the average of the squares of the rates of individual molecules: $v = \sqrt{3RT/M_r}$.
Here R is the universal gas constant; T is the absolute temperature of the gas; and M_r is the relative molecular mass of the gas.
At normal conditions, the expression for the root-mean-square rate (in m/s) assumes the form $v = 2610/\sqrt{M_r}$. Consequently, the heavier the molecules, the more slowly they move at equal temperatures. By way of example, consider the data:

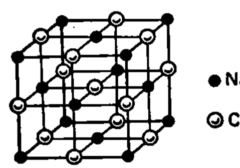
Gas	M_r	v, m/s (km/h)
Hydrogen H_2	2	1840 (6600)
Nitrogen N_2	28	493 (1700)
Oxygen O_2	32	460 (1625)
Hydrogen bromide HBr	81	290 (1045)

82. (3).
83. (1). On diffusion through a porous membrane, not only the molecular mass of the gaseous substances should be taken into account but also the relative sizes of their molecules. Evidently, among the substances given in the problem, the ammonia molecule shows the smallest size and its diffusion rate through the porous partition will be the highest.
84. (3). The dependence of V on T is directly proportional, which is evident from the equation $PV/T =$ const or $PV = nRT$.
85. (4).
86. (4). Based on the Avogadro law.
87. (1). Bromine under ordinary conditions is a liquid.
88. 4.03×10^{23}. Calculation: $5 \times 6.02 \times 10^{23} \times 3/22.4$.
89. (3). Calculation: $12.0 \times 4 = 48.0$ (g).
90. (2). H_2S, HCl, and H_2 at ordinary conditions are gases, H_2O is a liquid.
91. (3). Melting points: SO_3, 16.8 °C; I_2, 113.6 °C; NaCl, 801 °C.
92. (1) b; (2) c; (3) d; (4) a.
93. (4). After removal of the oxygen from the system the pressure in the vessel will be 50.6 kPa.
94. (2). The values of the boiling points for the molecular compounds are defined by the forces of intermolecular attraction and depend on such factors as polarity, the presence of hydrogen bonds, and others. For example, HF shows a higher boiling point than neon and carbon(II) oxide due to the presence of hydrogen bonds. Carbon(II) oxide boils at a relatively lower temperature because it has the largest relative molecular mass and a definite polarity. Neon has the lowest boiling temperature, since its monatomic molecule is non-polar. The ionic compound $BaCl_2$ exhibits a high boiling temperature owing

to the strong bonding between the ions. Indeed, the boiling points of the substances under discussion have the following values: Ne, 27 K; CO, 83 K; HF, 293 K; and $BaCl_2$, 1813 K.

95. (3). O—H ... Cl bond is the weakest, since the chlorine atom has a relatively large size and is a poor donor of the electron pair. The hydrogen bond O—H ... N is stronger than the hydrogen bond N—H ... O, since O—H exhibits a higher polarity than N—H. Thus: O—H ... Cl < N—H ... O < O —H ... N.

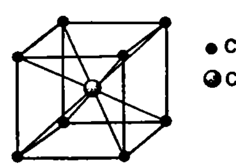
96. (3). The crystal structure of MgO is related to the coordination type of crystal



The NaCl structural type (a face-centered cube)

lattices of the composition AB. The most widespread octahedral-octahedral coordination (NaCl geometry, the sodium ion has a coordination number of six) and the cubic-cubic coordination (CsCl geometry, the cesium ion exhibits a coordination number of eight).

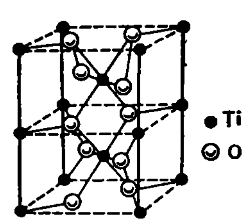
Since the coordination number of the magnesium ion in magnesium oxide is six, the



The CsCl geometry (a body-centered cube)

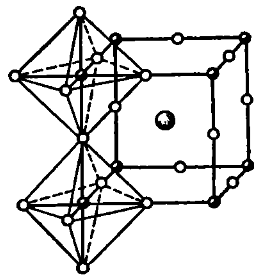
crystal lattice of magnesium oxide is of the NaCl type (a face-centered cube).

Rutile TiO_2 is a coordination crystal of the AB_2 composition, it exhibits an octahedral-trigonal coordination



Rutile TiO_2

An example of the coordination lattice of a three-element compound is the mineral perovskite $CaTiO_3$: each titanium atom in $CaTiO_3$ is surrounded by six oxygen atoms (positioned at the vertices of the octahedron) and the calcium atom, by twelve oxygen atoms.

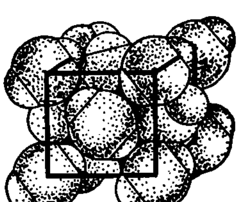


Perovskite $CaTiO_3$

97. (2). The oxidation state of carbon in CO_2 is $+4$, i.e. all the four valence electrons of the central atom are used in bond formation.
Two σ-bonding electron pairs correspond to the central atom coordination number of 2; the molecule is linear.
Based on the valence bond theory, formation of two σ-bonds involves one *s*- and one *p*-orbital (*sp*-hybridization). The two remaining electrons of the carbon atom and one at a time from two oxygen atoms participate in π-bond formation.
Thus, the structure of the CO_2 molecule can be represented in this manner:

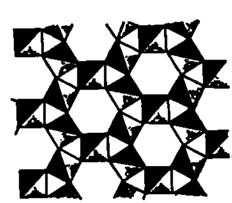
$$O \underset{\pi}{\overset{\sigma}{=}} C \underset{\pi}{\overset{\sigma}{=}} O$$

98. Carbon dioxide; silicon dioxide; SiO_2; CO_2.



← The molecular lattice of solid CO_2

The atomic lattice of SiO_2 →



99. (1) b; (2) a; (3) c; (4) d.

100.

	C_2H_4	N_2H_4	H_2O_2	H_2F_2
(1)	+	+	+	
(2)	+			
(3)	+			+
(4)		+	+	+
(5)		+	+	+
(6)		+		

Section 1.3

1. (1) Na_3PO_4 (3) SO_2
   (2) NaOH (4) H_2SO_4
2. (1) $CaCO_3$ (3) Mg(OH)Cl
   (2) $KHSO_4$ (4) K_2NaPO_4
3. (4). The acids H_2SO_4, H_2CO_3, and H_3PO_4 correspond to the oxides SO_3, CO_2, and P_2O_5, respectively.
4. SiO_2, P_2O_5, MgO, ZnO, CaO. Two of the five oxides listed (MgO and CaO) can react with the solvent (water).
5. (3). $SO_3 + H_2O = H_2SO_4$.
6. CrO. Chromium(II) oxide; the relevant base is $Cr(OH)_2$.
7. (2).
8. CuO, Na_2O, and MnO.
9. (1) Cl_2O_7, P_2O_5, Mn_2O_7;
   (2) CaO, Na_2O, CrO, NiO;
   (3) Cr_2O_3, Al_2O_3, ZnO.

10.

HBr	(4)	CH_3COOH	(1)
HClO	(3)	H_2S	(6)
H_2SO_3	(5)	HNO_2	(8)
$HClO_4$	(2)	$H_4P_2O_7$	(7)

11.

$Al(OH)_3$	(7)	$Ca(OH)_2$	(2)
$Cu(OH)_2$	(6)	$Ba(OH)_2$	(3)
$Fe(OH)_3$	(5)	$Zn(OH)_2$	(8)
NaOH	(1)	RbOH	(4)

12. (4).
13. (2).
14. (4).
15. (3). $KOH + SO_3 = KHSO_4$;

$$2KOH + SO_3 = K_2SO_4 + H_2O.$$

16. (1) Sodium bisulphate — Acidic
(2) Hydroxocopper(II) carbonate — Basic
(3) Barium selenate — Neutral
(4) Hydroxoiron(II) nitrate — Basic
(5) Lithium carbonate — Neutral

17. (3). $\omega(O) = 2A_r(O)/M_r(SO_2) = 2 \times 16/64 = 0.5$ or 50%.
18. (2). $Fe + H_2SO_4 = FeSO_4 + H_2\uparrow$.
19. (3). $LiH + H_2O = LiOH + H_2\uparrow$.
20. (2). $Zn + 2NaOH + 2H_2O = Na_2[Zn(OH)_4] + H_2\uparrow$.
21. (4).
22. (2). $Cu + 4HNO_3$ (conc.) $= Cu(NO_3)_2 + 2NO_2\uparrow + 2H_2O$.
23. (3). Both are acidic oxides.
24. $Fe_3O_4(FeO \cdot Fe_2O_3)$; $Fe_3O_4 + 8HCl = 2FeCl_3 + FeCl_2 + 4H_2O$.
25. (4). $2Al + 6KOH + 6H_2O = 2K_3[Al(OH)_6] + 3H_2\uparrow$.
26. (1) CO_2 (2) SO_3 (3) P_2O_5 (4) N_2O_5 (5) SeO_3 (6) As_2O_3
27. (4). $Zn + H_2SO_4 = ZnSO_4 + H_2\uparrow$; 6.02×10^{22} atoms correspond to 0.1 mole zinc; 0.1 mole hydrogen evolves, i.e. 0.2 g.
28. (2).
29. (2). $2Al + 6NaOH + 6H_2O = 2Na_3[Al(OH)_6] + 3H_2\uparrow$.
30. (1) NaH_2PO_4 — Acidic
(2) NH_4HSO_4 — Acidic
(3) $Fe_2(SO_4)_3$ — Neutral
(4) $Ca(HCO_3)_2$ — Acidic
(5) $Fe(OH)_2Cl$ — Basic
(6) Na_2SiO_3 — Neutral
(7) $(CuOH)_2CO_3$ — Basic
31. (2).
32. (4).
33. (3). $(CuOH)_2CO_3 \xrightarrow{T} 2CuO + H_2O + CO_2\uparrow$;
$CuO + H_2 \xrightarrow{T} Cu + H_2O$.
34. (4). $Fe_2O_3 + 3H_2 \xrightarrow{T} 2Fe + 3H_2O$.

35. (4). $AlCl_3 + 3NaOH = Al(OH)_3\downarrow + 3NaCl$;
$2Al(OH)_3 + 3H_2SO_4 = Al_2(SO_4)_3 + 6H_2O$;
$Al(OH)_3 + 3KOH = K_3[Al(OH)_6]$.

36. (4).

37. (2). $Mg(OH)_2 + H_2SO_4 = MgSO_4 + 2H_2O$.

38. (4).

39. $AlCl_3 + 3NaOH = Al(OH)_3\downarrow + 3NaCl$; $AlCl_3$.
Aluminium hydroxide can also be produced if the solutions of ammonium hydroxide or sodium carbonate are used as reagents; an excess of an aluminium salt is not a must:

$AlCl_3 + 3NH_4OH = Al(OH)_3\downarrow + 3NH_4Cl$;
$2AlCl_3 + 3Na_2CO_3 + 3H_2O = 2Al(OH)_3\downarrow + 6NaCl + 3CO_2\uparrow$

(the reaction proceeds through the hydrolysis of the carbonate ion:

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

and a basic pH of the solution).

40. (3). $AlCl_3 + \underset{\text{(deficiency)}}{3NaOH} = Al(OH)_3\downarrow + 3NaCl$.

41. (4). $Ca(OH)_2 + CO_2 = CaCO_3\downarrow + H_2O$.

42. (2). The left-hand beaker will become heavier as a result of the absorption of carbon dioxide in the reaction

$2NaOH + CO_2 = Na_2CO_3 + H_2O$.

43. Has dissolved (in both test tubes).

$Zn(OH)_2 + 2HNO_3 = Zn(NO_3)_2 + 2H_2O$;
$Zn(OH)_2 + 2NaOH = Na_2ZnO_2 + 2H_2O$.

44. $CuSO_4 \xrightarrow{KOH} \mathbf{Cu(OH)_2} \xrightarrow{T} \mathbf{CuO} \xrightarrow{H_2,\ T} Cu$.

45. (1) $2FeSO_4 + 2H_2O \xrightarrow{\text{electrolysis}} 2Fe + O_2\uparrow + 2H_2SO_4$;
(2) $3Fe + 2O_2 \xrightarrow{T} Fe_3O_4$;
(3) $3Fe_3O_4 + 28HNO_3 \text{ (dilute)} = 9Fe(NO_3)_3 + NO\uparrow + 14H_2O$.

46. BaO, Li_2O, SO_3, CaO, P_2O_5, and Na_2O.
$BaO + H_2O = Ba(OH)_2$ $\quad$ $CaO + H_2O = Ca(OH)_2$

$Li_2O + H_2O = 2LiOH$ $P_2O_5 + 3H_2O = 2H_3PO_4$
$SO_3 + H_2O = H_2SO_4$ $Na_2O + H_2O = 2NaOH$

47. (1) $Ca + 2H_2O = Ca(OH)_2 + H_2\uparrow$;
(2) $Ca + 2HCl = CaCl_2 + H_2\uparrow$;
(3) $Ca + H_2O + CO_2 = CaCO_3 + H_2\uparrow$;
(4) $2Ca + O_2 \xrightarrow{T} 2CaO$.

48. (1) $2Al + 3Cl_2 = 2AlCl_3$;
$2Al + 6HCl = 2AlCl_3 + 3H_2\uparrow$;
(2) $4Al + 3O_2 = 2Al_2O_3$;
(3) $2Al + 6H_2O = 2Al(OH)_3 + 3H_2\uparrow$;
(4) $2Al + 3H_2SO_4 = Al_2(SO_4)_3 + 3H_2\uparrow$.

49. (1) $CuO + 2HCl = CuCl_2 + H_2O$;
(2) $CuO + H_2SO_4 = CuSO_4 + H_2O$;
(3) $CuO + 2HNO_3 = Cu(NO_3)_2 + H_2O$;
(4) $CuO + H_2 \xrightarrow{T} Cu + H_2O$.

50. (1) $NaOH + Al(OH)_3 = NaAlO_2 + 2H_2O$;
(2) $2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$;
(3) $2NaOH + CO_2 = Na_2CO_3 + H_2O$;
(4) $\underset{\text{(deficiency)}}{NaOH} + H_3PO_4 = NaH_2PO_4 + H_2O$.

51. (1) $Zn(OH)_2 + H_2SO_4 = ZnSO_4 + 2H_2O$;
(2) $Zn(OH)_2 + 2HNO_3 = Zn(NO_3)_2 + 2H_2O$;
(3) $Zn(OH)_2 \xrightarrow{T} ZnO + H_2O$;
(4) $Zn(OH)_2 + 2KOH = K_2ZnO_2 + 2H_2O$.

52. (1) $2Fe + 3Cl_2 \xrightarrow{T} 2FeCl_3$;
(2) $4Fe + 3O_2 = 2Fe_2O_3$ (slow oxidation);
(3) $Fe_2O_3 + 3H_2SO_4 = Fe_2(SO_4)_3 + 3H_2O$;
(4) $Fe_2O_3 + 6HCl = 2FeCl_3 + 3H_2O$;
(5) $FeCl_3 + 3NaOH = Fe(OH)_3\downarrow + 3NaCl$;
(6) $2Fe(OH)_3 + 3H_2SO_4 = Fe_2(SO_4)_3 + 6H_2O$;
(7) $2Fe(OH)_3 \xrightarrow{T} Fe_2O_3 + 3H_2O$.

53. (1) $Cr + 2HCl = CrCl_2 + H_2\uparrow$;
(2) $4Cr + 3O_2 = 2Cr_2O_3$;
(3) $CrCl_2 + 2NaOH = Cr(OH)_2\downarrow + 2NaCl$;

(4) $Cr_2O_3 + 6HCl = 2CrCl_3 + 3H_2O$;
(5) $CrCl_3 + 3NaOH = Cr(OH)_3\downarrow + 3NaCl$;
(6) $4Cr(OH)_2 + 2H_2O + O_2 = 4Cr(OH)_3$;
(7) $Cr(OH)_3 + NaOH = NaCrO_2 + 2H_2O$;
(8) $Cr(OH)_3 + 3HCl = CrCl_3 + 3H_2O$;
(9) $2NaCrO_2 + 2NaOH + 3H_2O_2 = 2Na_2CrO_4 + 4H_2O$;
(10) $2CrCl_3 + 2NaCl + 3H_2O_2 + H_2O = Na_2Cr_2O_7 + 8HCl$;
(11) $2Na_2CrO_4 + 2HCl$ (dilute) $= Na_2Cr_2O_7 + 2NaCl + H_2O$.

54. (1) $4P + 5O_2 = 2P_2O_5$;
(2) $P_2O_5 + 3H_2O = 2H_3PO_4$;
(3) $2H_3PO_4 + 3Ca(OH)_2 = Ca_3(PO_4)_2\downarrow + 6H_2O$;
(4) $Ca_3(PO_4)_2 + 5C + 3SiO_2 = 2P + 5CO\uparrow + 3CaSiO_3$.

55. (1) $Cu \rightarrow CuO \rightarrow Cu(OH)_2 \rightarrow CuSO_4$;
(2) $S \rightarrow SO_2 \rightarrow H_2SO_3 \rightarrow Na_2SO_3$;
(3) $Ca \rightarrow CaO \rightarrow Ca(OH)_2 \rightarrow CaCO_3$;
(4) $C \rightarrow CO_2 \rightarrow H_2CO_3 \rightarrow CaCO_3$.

We now give equations for all chemical reactions:

(1) $2Cu + O_2 = 2CuO$;
$CuO + 2HCl = CuCl_2 + H_2O$;
$CuCl_2 + 2NaOH = Cu(OH)_2\downarrow + 2NaCl$;
$Cu(OH)_2 + H_2SO_4 = CuSO_4 + 2H_2O$.
(2) $S + O_2 = SO_2$;
$SO_2 + H_2O = H_2SO_3$;
$H_2SO_3 + 2NaOH = Na_2SO_3 + 2H_2O$.
(3) $2Ca + O_2 = 2CaO$;
$CaO + H_2O = Ca(OH)_2$;
$Ca(OH)_2 + H_2CO_3 = CaCO_3\downarrow + 2H_2O$.
(4) $C + O_2 = CO_2$;
$CO_2 + H_2O = H_2CO_3$;
$H_2CO_3 + Ca(OH)_2 = CaCO_3\downarrow + 2H_2O$.

56. For example, from sulphur and calcium:

$$\left.\begin{matrix} S \rightarrow SO_2 \rightarrow H_2SO_3 \\ Ca \rightarrow CaO \rightarrow Ca(OH)_2 \end{matrix}\right\} \rightarrow CaSO_3.$$

57. Based on Na and P:

$$\left.\begin{array}{l} Na \rightarrow Na_2O \\ P \rightarrow P_2O_5 \end{array}\right\} \rightarrow Na_3PO_4.$$

or Mg and C

$$\left.\begin{array}{l} Mg \rightarrow MgO \\ C \rightarrow CO_2 \end{array}\right\} \rightarrow MgCO_3.$$

58. (1). $CaCO_3 \xrightarrow{T} \underset{\text{Basic oxide}}{CaO} + \underset{\text{Acidic oxide}}{CO_2\uparrow}.$

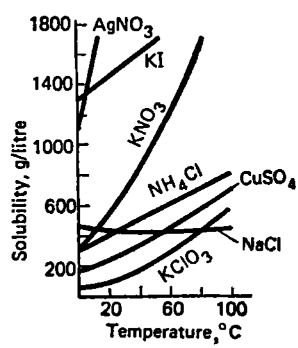
59. (1) $Na_2O + H_2O = 2NaOH$;
(2) $CO_2 + 2KOH = K_2CO_3 + H_2O$;
(3) $FeCl_3 + 3NaOH = Fe(OH)_3\downarrow + 3NaCl$;
(4) $2Al + 6H_2O = 2Al(OH)_3 + 3H_2\uparrow$.

60. (3). All the other reactions can occur.

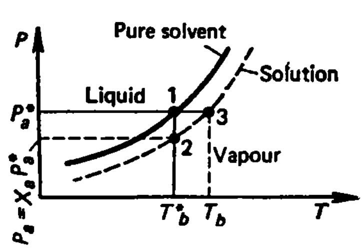
Section 1.4

1. (1) a; (2) c; (3) a; (4) a; (5) b; (6) a.
2. (1) $H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$;
$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$;
(2) $Ca(OH)_2 \rightleftharpoons CaOH^+ + OH^-$;
$CaOH^+ \rightleftharpoons Ca^{2+} + OH^-$;
(3) $NaHCO_3 \rightleftharpoons Na^+ + HCO_3^-$;
$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$;
(4) $MgOHCl \rightleftharpoons MgOH^+ + Cl^-$;
$MgOH^+ \rightleftharpoons Mg^{2+} + OH^-$.

3. Increases; decreases. Below are given the solubility curves for some salts. A variety of substances exhibit a decrease in their solubility with rising temperature. For example, the solubility of calcium hydroxide $Ca(OH)_2$ at 20°C is 1.6 g per 1000 g H_2O, at 60 °C, 1.14, and at 100 °C, only 0.72



4. (1). Mass of solution: $1000 + 219 = 1219$ (g); $M(CaCl_2) = 111$ g/mole. $m(CaCl_2) = 111$ g. $\omega(CaCl_2) = (m(CaCl_2)/m(\text{sln}) \times 100 = (111/1219) \times 100 = 9.1\%$.
5. (3).
6. (1) $NaOH \rightleftharpoons Na^+ + OH^-$;
   (2) $Fe(NO_3)_3 \rightleftharpoons Fe^{3+} + 3NO_3^-$;
   (3) $HNO_3 \rightleftharpoons H^+ + NO_3^-$;
   (4) $Ba(OH)_2 \rightleftharpoons Ba^{2+} + 2OH^-$.
7. (3).
   Solution of a mass of 100 g contains NaOH of a mass of 30 g
   Solution of a mass of 200 g contains NaOH of a mass of x g
   $x = 6$ g.
   NaOH of a mass of 6 g is contained in solution of a mass of 100 g
   NaOH of a mass of 60 g is contained in solution of a mass of x g
   $x = 1000$ g; $1000 - 200 = 800$ (g) of water is needed to be added to the initial solution.
8. (2). $SP(AgCl) = 1.8 \times 10^{-10}$; $SP(AgBr) = 5.3 \times 10^{-13}$; $SP(AgI) = 8.3 \times 10^{-17}$.
9. (3). $\underset{0.15\text{ mole}}{Mg(NO_3)_2} = \underset{0.15\text{ mole}}{Mg^{2+}} + \underset{0.30\text{ mole}}{2NO_3^-}$.
   0.15 mole $Mg(NO_3)_2$ forms 0.15 mole Mg^{2+} and 0.30 mole NO_3^-; a total of 0.45 mole of ions.
10. (4). 3 moles of ions, 4 moles of ions, 5 moles of ions.
11. (3). Hydrolysis reaction: $Al^{3+} + HOH \rightleftharpoons Al(OH)^{2+} + H^+$.
12. (2).
13. (4).
14. (4). Addition of common salt to water yields a solution whose boiling point exceeds that of pure solvent (water). An increase in the boiling point of a solution is one of the colligative properties of



solutions. It arises from a decrease in the vapour pressure of a pure solvent. This is evident from the figure that illustrates the influence of solute on the position of the liquid-vapour equilibrium curve for the solvent.

If P_a^* is the atmospheric pressure, and T_b^* denotes the boiling point of water (point 1), addition of the solute (common salt) causes a decrease in the vapour pressure from P_a^* to $P_a = X_a P_a^*$ (in proportion to the amount of the common salt added). This new value of the pressure is below the atmospheric one; therefore the solution at T_b^* does not boil. To make the solution boil again, it is necessary to elevate its temperature to the value T_b (thus passing from point 2 to point 3), where the vapour pressure becomes equal to the atmospheric one.

If in the first variant the cover on the beaker is airtight, the boiling point of the liquid can increase owing to an increase in pressure in the beaker.

15. 0.02. $M(CuSO_4 \cdot 5H_2O) = 249.7$ g/mole; the obtained solution contains $5/249.7 = 0.02$ mole.

16. (2).

17. (3).

18. (1). 1 litre of solution contains $40 \times 0.6 = 24$ g NaOH
0.5 litre of solution contains 12 g NaOH

19. (1).
1 litre of solution contains 0.2 mole KOH
0.250 litre of solution contains x mole KOH
$x = 0.2 \times 250/1 \doteq 0.05$ mole.

20. (3).

21. $\omega(NaCl) = 2.2\%$; $\omega(Na_2S) = 1.06\%$. Mixed are 100 g 5% solutions of Na_2S and $CuCl_2$ each:

$$\underset{134.5\ \text{g/mole}}{\overset{5\ \text{g}}{CuCl_2}} + \underset{78\ \text{g/mole}}{\overset{5\ \text{g}}{Na_2S}} = \underset{95.5\ \text{g/mole}}{CuS\downarrow} + \underset{58.5\ \text{g/mole}}{2NaCl}.$$

$\nu(CuCl_2) = 5/134.5 = 0.037$ mole; $\nu(Na_2S) = 5/78 = 0.064$ mole.

0.037 mole $CuCl_2$ has reacted completely to form 0.037 mole (3.5 g) of CuS precipitate and 2 ×

0.037 mole (4.33 g) of NaCl; the solution contains unreacted Na_2S in the amount: $0.064 - 0.037 = 0.027$ mole (2.1 g). The solution mass: $100 + 100 - 3.5 = 196.5$ (g).
Thus, the mass percent of NaCl is $4.33 \times 100/196.5 = 2.2\%$, and the mass percent of Na_2S, $2.1 \times 100/196.5 = 1.06\%$.

22. (4). The plot suggests that the solubility of 50 g of a substance in 100 g of water corresponds to 70 °C.
23. (2).
24. (2).
25. (4).
26. (4). $H_2SO_4 + BaCl_2 = BaSO_4\downarrow + 2HCl$.
27. (3). $\omega(Na_2CO_3) = 218 \times 100/(1000 + 218) = 17.8\%$.
28. (2). $500 - 200 = 300$ (g).
29. (3). $M(CoCl_2) = 130$ g/mole; $M(CoCl_2 \cdot 6H_2O) = 238$ g/mole, i.e. 476 g of $CoCl_2 \cdot 6H_2O$ constitute 2 moles, the solution will contain 2 moles of $CoCl_2$ (2×130 g).
100 g of solution contains 13.15 g of $CoCl_2$
x g of solution contains 260 g of $CoCl_2$
$x = 260 \times 100/13.15 = 1976$ (g), hence, the mass of water required to dissolve the crystal hydrate is: $1976 - 476$ (the mass of the crystal hydrate) $= 1500$ (g).
30. (2).

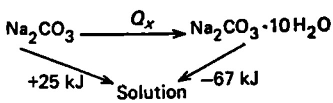
50 g HNO_3 contains 100 g of solution
x g HNO_3 contains 250×1.3 g of solution
$x = 50 \times 250 \times 1.3/100 = 162.5$ g.
$\omega(HNO_3) = 162.5 \times 100/(1000 + 325) = 12.2\%$.

31. (2).
32. (4). $M_r(FeSO_4) = 152$; $M_r(FeSO_4 \cdot 7H_2O) = 278$.
5 g $FeSO_4$ must be contained in 100 g of solution
x g $FeSO_4$ must be contained in 10 000 g of solution
$x = 5 \times 10\,000/100 = 500$ g of iron sulphate.
278 g of crystal hydrate contains 152 g $FeSO_4$
x g crystal hydrate contains 500 g $FeSO_4$
$x = 278 \times 500/152 = 914$ g $FeSO_4 \cdot 7H_2O$.
33. (2). $M_r(MnSO_4) = 151$; $A_r(Mn) = 55$; x is the number of moles of H_2O in one mole of the crystal hydrate.

24.66% corresponds to 55 g
100% corresponds to $(151 + 18 \cdot x)$ g
$x = 4$; the formula reads $MnSO_4 \cdot 4H_2O$.

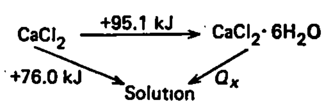
34. (4). $M_r(LiCl) = 42.4$; $A_r(Li) = 6.9$; x is the number of H_2O moles in one mole of the crystal hydrate.
7.19% corresponds to 6.9 g
100% corresponds to $(42.4 + 18 \cdot x)$ g
$x = 3$; the formula reads $LiCl \cdot 3H_2O$.

35. (1).

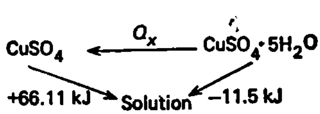


$$Q_x = +25 - (-67) = +92 \quad (kJ).$$

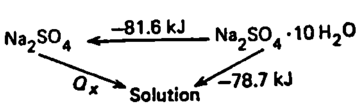
36. —19.1 (absorption of heat).
$$Q_x = -95.1 + 76.0 = -19.1 \ (kJ).$$



37. —77.61 (absorption of heat).
$$Q_x = -\ (+66.11 + 11.5) = -77.61 \ (kJ).$$



38. (1).



$$Q_x = -(-81.6) - 78.7 = +2.9 \ (kJ).$$

39. (3). $Na_3PO_4 \rightleftarrows 3Na^+ + PO_4^{3-}$.

40. (4).

$$FeCl_3 = Fe^{3+} + 3Cl^-$$

0.1 mole 0.1 mole 0.3 mole

$0.1 + 0.3 = 0.4$ (mole of ions).

41. (1).

42. $Ca(HCO_3)_2 \xrightarrow{T} CaCO_3 + H_2O + CO_2\uparrow$;

$Ca(HCO_3)_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaHCO_3$;

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$.

43. (2).

44. $MgSO_4 + Na_2CO_3 \rightarrow MgCO_3\downarrow + Na_2SO_4$.

45. (4).

4.0 g NaOH is contained in 2 litres of solution

x g NaOH is contained in 1 litre of solution

$x = 2$ g.

40 g NaOH corresponds to 1 mole

2 g NaOH corresponds to x mole

$x = 0.05$ mole/litre.

46. (2).

47. (2).

48. (1).

0.15 mole is contained in 1 litre of solution

x mole is contained in 0.050 litre of solution

$x = 0.0075$ mole NaOH; M(NaOH) = 40 g/mole,

the sample mass is $0.0075 \times 40 = 0.30$ (g).

49. (4).

50. (1).

51. (3).

52. (4).

53. (3).

$$Al_2(SO_4)_3 = 2Al^{3+} + 3SO_4^{2-}$$

0.1 mole 0.2 mole 0.3 mole

The molar concentration of SO_4^{2-} is 0.3 mole/litre.

54. (4). $HCl + NaOH = NaCl + H_2O$.

1 litre of solution contains 2 moles NaOH

0.050 litre of solution contains x moles NaOH

$x = 0.1$ mole.

0.025 litre of solution contains 0.1 mole HCl

1 litre of solution contains x moles HCl

$x = 4$ moles, i.e. the HCl concentration is 4 mole/litre.

55. (3). Hydrolysis:
$Na_2CO_3 + H_2O \rightleftharpoons NaHCO_3 + NaOH$;
$CO_3^{2-} + HOH \rightleftharpoons HCO_3^- + OH^-$.

56. (3). $HCl = H^+ + Cl^-$, i.e. $[H^+] = 1 \times 10^{-2}$ mole/litre.

57. (2). $pH = -\log [H^+] = \log 10^{-2} = 2$.

58. (4). $pH = 14 - \log [H^+] = 14 - 2 = 12$.

59. (4).

60. (4).

61. (4). Solutions capable of maintaining an essentially constant pH value were named *buffer solutions*. They commonly contain a mixture of solutions of a weak acid and a salt formed by this acid and a strong base, or a solution of a weak base and a salt of this base and a strong acid.

62. (4).

63. (4).

64. (3). Carbonate buffer mixture.

65. (3). Dihydrogen sodium phosphate. On dissolution of the salts indicated in the test, the solution pH changes due to hydrolysis:

(1) $Na_2SO_3 + H_2O \rightleftharpoons NaHSO_3 + NaOH$;
$SO_3^{2-} + HOH \rightleftharpoons HSO_3^- + OH^-$;
(2) $Na_2HPO_4 + H_2O \rightleftharpoons NaH_2PO_4 + NaOH$;
$HPO_4^{2-} + HOH \rightleftharpoons H_2PO_4^- + OH^-$;
(3) $NaH_2PO_4 + H_2O \rightleftharpoons H_3PO_4 + NaOH$;
$H_2PO_4^- + HOH \rightleftharpoons H_3PO_4 + OH^-$;
(4) $Na_3PO_4 + H_2O \rightleftharpoons Na_2HPO_4 + NaOH$;
$PO_4^{3-} + H_2O \rightleftharpoons HPO_4^{2-} + OH^-$.

It would seem that in all cases the hydrolysis of these salts would make the solution basic. But in dihydrogen sodium phosphate solution, dihydrogen phosphate ion dissociates in this manner:

$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$

and this dissociation dominates over the hydrolysis process. This leads to the acidic pH of the solution of dihydrogen sodium phosphate.

66. (1). Hydrogen sodium phosphate.
(1) $HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$;
(2) $Al^{3+} + H_2O \rightleftharpoons (AlOH)^{2+} + H^+$;

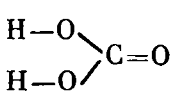
(3) $H_2PO_4^- + H_2O \rightleftharpoons H_3PO_4 + OH^-$;
$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$;
(4) $Fe^{3+} + H_2O \rightleftharpoons (FeOH)^{2+} + H^+$.

A basic solution will only be due to the dissolution of hydrogen sodium phosphate in water. Dissolution of the other salts will make the solution acidic. Consider the explanation given in the preceding answer for the elucidation of the fact that dihydrogen sodium phosphate dissolution in water acidifies the solution.

67. (1) Basic $CO_3^{2-} + HOH \rightleftharpoons HCO_3^- + OH^-$;
(2) Acidic $Fe^{3+} + HOH \rightleftharpoons (FeOH)^{2+} + H^+$;
(3) Acidic $Cu^{2+} + HOH \rightleftharpoons (CuOH)^+ + H^+$;
(4) Neutral $NH_4^+ + CH_3COO^- + HOH \rightleftharpoons NH_4OH + CH_3COOH$.

68. (2). $NH_4^+ + HOH \rightleftharpoons NH_4OH + H^+$.

69. (2). $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$; the dissociation constant of carbonic acid already for the first step shows the lowest value as compared with the other acids. It should be borne in mind that for aqueous solutions of carbonic acid, the value of the dissociation constant for the first step is given ($K_1 = [H^+][HCO_3^-]/([H_2CO_3] = 4.2 \times 10^{-7})$ disregarding the fact that not all of the CO_2, which is dissolved but not dissociated, is present in solution as $H_2CO_3(CO_2 \cdot aq)$. If one takes into account the real concentration of H_2CO_3, then $K_1 = 2 \times 10^{-4}$, which generally speaking, corresponds to the structure of the acid $(HO)_2CO$ rather than H_2CO_3:



70. (1). The equilibrium of the hydrolysis reaction
$Fe^{3+} + HOH \rightleftharpoons FeOH^{2+} + H^+$
is shifted to the left once the concentration of the H^+ ions increases in the system, i.e. when HCl is added.

71. (3). $pH = -\log [H^+]$, i.e. the numerical value of pH decreases with increasing H^+ concentration.

72. (2).

73. (3). The capacity of a buffer solution (see the answer to Problem 61) to maintain the pH value nearly constant starts from the fact that one constituent of the solution binds hydrogen ions, and the other, hydroxyl ions. Examples of buffer solutions are: CH_3COOH and CH_3COONa (acetate buffer); NH_4OH and NH_4Cl (ammonium buffer); H_2CO_3 and $NaHCO_3$, $NaHCO_3$ and Na_2CO_3 (carbonate buffers); NaH_2PO_4 and Na_2HPO_4 (phosphate buffer); the pH for the buffer solution can be calculated using the formulas:

$$\text{pH} = \text{p}K - \log\frac{C_{\text{acid}}}{C_{\text{salt}}}, \text{pH} = \text{p}K - \log\frac{C_{\text{base}}}{C_{\text{salt}}}$$

where the strength of an acid (or a base) is $\text{p}K = -\log K$, and K is the dissociation constant of an acid or a base. The calculations show that the pH of the buffer mixtures listed above (for the mole ratio of the mixture 1:1) are:

acetate buffer 4.7	ammonium buffer 9.3
carbonate buffer 6.4	phosphate buffer 6.8

These data indicate that the ammonium buffer is most suitable for maintaining pH 9 in an aqueous solution (see Problem 3). If an acid is added to the ammonium buffer solution, hydrogen ions start reacting with a weak base (NH_4OH):

$$NH_4OH + H^+ \rightleftharpoons NH_4^+ + H_2O$$

with the formation of slightly ionized water molecules. The consumption of OH^- ions is balanced out by the dissociation of NH_4OH, and the pH of the solution remains essentially unchanged. Once an alkali is added to this buffer solution the OH^- ions become bound with NH_4^+ ions which are present in solution in large quantities due to the dissociation of the ammonium salt:

$$NH_4^+ + OH^- \rightleftharpoons NH_4OH(NH_3 \cdot H_2O).$$

Thus, the OH^- ion concentration in the solution does not grow and the pH remains constant (of course, in certain limits, which are called the *buffering power*

of the solution). These processes proceed in a similar manner on addition of small amounts of acid or alkali to other buffer solutions.

The correct answer can also be found without calculating the pH value of the buffer solution. The qualitative analysis of the pairs of substances considered in the problem indicates that a basic medium characterizes the solution only when the ammonium pair is used. All the other pairs produce weakly acidic media.

The mechanism of action of the phosphate buffer solution is similar to those of the other buffers. Here the dihydrogen phosphate ion acts as a weak acid and binds OH^- ions:

$$H_2PO_4^- + OH^- \rightleftharpoons HPO_4^{2-} + H_2O$$

and the hydrogen phosphate ion, as a weak base, binding H^+ ions:

$$HPO_4^{2-} + H^+ \rightleftharpoons H_2PO_4^-.$$

Since dihydrogen phosphates form $H_2PO_4^-$ ions dissociating according to the scheme: $H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$, and hydrogen phosphates, HPO_4^{2-} ions dissociating but negligibly: $HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$, dihydrogen phosphates can be regarded as a weak acid and biphosphates, as its salt.

74. (4). $PO_4^{3-} + HOH \rightleftharpoons HPO_4^{2-} + OH^-$, i.e. the solution is basic.

75. (3). $CrCl_3 + 3NaOH = Cr(OH)_3\downarrow + 3NaCl$.

76. (1). $NH_3 + HOH \rightleftharpoons NH_4^+ + OH^-$.

77. (1). $Na_2CO_3 \rightleftharpoons 2Na^+ + CO_3^{2-}$;

$$CO_3^{2-} + HOH \rightleftharpoons HCO_3^- + OH^-;$$

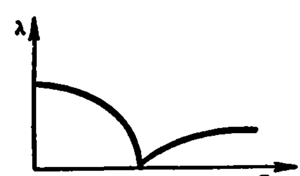
a weakly basic solution, the pH value exceeds 7.

78. $Ca(OH)_2 + CO_2 =$

$CaCO_3\downarrow + H_2O$;

$CaCO_3 + CO_2 + H_2O =$

$Ca(HCO_3)_2$.



On passing CO_2 through a solution, the electric conductivity will first rapidly fall, since insoluble $CaCO_3$ is formed, and then gradually rise due to the formation of an acidic salt dissociating by the scheme: $Ca(HCO_3)_2 \rightleftarrows Ca^{2+} + 2HCO_3^-$.

79. $\mathbf{FeOH^{2+} + HOH} \rightarrow Fe(OH)_2^+ + H^+$; $FeOH^{2+}$, in turn, is the product of hydrolysis of any soluble salt of Fe^{3+}.

80. $\mathbf{Al_2(SO_4)_3 + 3Na_2CO_3 + 3H_2O} = 2Al(OH)_3\downarrow + 3CO_2\uparrow + 3Na_2SO_4$.

81. Zn (solid) $\rightarrow Zn^{2+} + 2\bar{e}$;
$2MnO_2$ (solid) $+ 8NH_4^+ + 2\bar{e} \rightarrow 2Mn^{3+} + 4H_2O + 8NH_3$.

82. Pb (solid) $+ SO_4^{2-} \rightarrow PbSO_4$ (solid) $+ 2\bar{e}$;
PbO_2 (solid) $+ 4H^+ + SO_4^{2-} + 2\bar{e} \rightarrow PbSO_4$ (solid) $+ 2H_2O$.

83. 49 and 24.5. Electrolysis brings about decomposition of water alone, i.e. the amount of potassium sulphate in solution remains constant.
Mass of water in solution: (a) prior to electrolysis $m(H_2O) = 150$ g; (b) after electrolysis $m(H_2O) = m(\text{sln}) - m(K_2SO_4) = (20/0.15) - 20 = 113.3$ (g).
Mass of water decomposed on electrolysis: $m\ (H_2O) = 150 - 113.3 = 36.7$ (g), i.e. $\nu\ (H_2O) = 2.04$ mole. Since $2H_2O = 2H_2 + O_2$, we have $\nu\ (H_2) = 2.04$ mole, and $\nu\ (O_2) = 1.02$ mole, hence:
$V\ (H_2) = \nu\ (H_2)\cdot RT/P = 2.04 \times 8.134 \times 293.15/101325 = 0.049\ (m^3) = 49$ litres;
$V\ (O_2) = V\ (H_2)/2 = 0.049/2 = 0.0245\ m^3 = 24.5$ litres.

84. (1). $Fe^0 - 2\bar{e} = Fe^{2+}$,
$Cu^{2+} + 2\bar{e} = Cu^0$

85. $Zn^0 + Fe^{2+} = Zn^{2+} + Fe^0$;
$Zn^0 + Pb^{2+} = Zn^{2+} + Pb^0$;
$Zn^0 + Cu^{2+} = Zn^{2+} + Cu^0$;
$Pb^0 + Cu^{2+} = Pb^{2+} + Cu^0$

	Zn^{2+}	Fe^{2+}	Pb^{2+}	Cu^{2+}
Zn		+	+	+
Pb	−	−		+

86. $Ni^{2+} + 2\bar{e} = Ni^0$ and $Ni^0 - 2\bar{e} = Ni^{2+}$.
In addition, hydrogen can be released at the platinum cathode in the process: $2H_2O + 2\bar{e} = H_2\uparrow + 2OH^-$. The anode dissolution of metal is used in the production of pure nickel (electrolytic refining).

87. Copper; oxygen. The net equation for the electrolysis process

$$2Cu(NO_3)_2 + 2H_2O \xrightarrow{\text{electrolysis}} 2Cu + O_2\uparrow + 4HNO_3.$$

At the cathode: $Cu^{2+} + 2\bar{e} = Cu^0$.

At the anode: $2H_2O - 4\bar{e} = O_2\uparrow + 4H^+$.

88. (1). $Ag^+ + \bar{e} = Ag^0$.

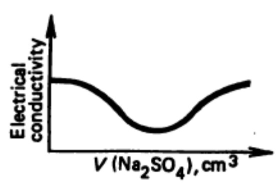
89. (1).

$$2NaCl + 2H_2O \xrightarrow{\text{electrolysis}} H_2\uparrow + Cl_2\uparrow + 2NaOH.$$

At the cathode: $2H_2O + 2\bar{e} = H_2\uparrow + 2OH^-$.

90. $BaCl_2 + Na_2SO_4 = BaSO_4\downarrow + 2NaCl$; further an excess of electrolyte Na_2SO_4:

$$Na_2SO_4 \rightleftarrows 2Na^+ + SO_4^{2-}.$$



91. To Svante Arrhenius.

Svante August Arrhenius (1859-1927). The Swedish chemist and physicist, one of the founders of the modern science of physical chemistry. A member of the Swedish Academy of Sciences (1901). Among his many published works are *Theories of Solutions*, *Chemical Kinetics Theory Development*, and *Electrolyte Solution Research*. He was the first to explain the essence of the temperature dependence of the reaction rate and introduced the notion of activation energy. Member of many academies of sciences and scientific societies.

A foreign member of St. Petersburg Academy of Sciences (1903). An honorary member of the USSR Academy of Sciences (1926). Nobel prize winner for chemistry (1903).

Section 1.5

1. (1). $CuO + H_2 = Cu + H_2O$.
   (2). $2Cu + O_2 = 2CuO$.
   (3) $Cu + O_2 = CuO_2$ (this compound is not formed and does not exist).
   (4) $Cu + H_2SO_4 \neq$ (the reaction does not go).
   (5) $CuO + H_2SO_4 = H_2O + CuSO_4$.
2. (1).
3. (2), (3), (4), (9);
   (1), (5), (6), (7), (8), (10).
4. (2).
5. $\underset{\text{blue solution}}{Fe + CuCl_2} \rightarrow \underset{\text{greenish solution}}{FeCl_2} + Cu\downarrow$; (3).
6. (4). The neutralization reaction occurs when an acid solution is mixed with a base solution. In the laboratory, neutralization is realized if the amounts of acid and base are stoichiometrically equivalent.
7. (1) b; (2) d; (3) a; (4) c.
8. (2).
9. (1).
10. (4).
11. (2). $Fe + 2HCl = FeCl_2 + H_2\uparrow$.
12. (4). $CaO + H_2O = Ca(OH)_2$.
13. (3).
14. (3).
15. (3).
16. (1) $2Fe(OH)_3 = Fe_2O_3 + \mathbf{3H_2O}$
    (2) $4Fe + \mathbf{3O_2} = 2Fe_2O_3$;
    (3) $Fe + \mathbf{H_2SO_4} = FeSO_4 + \mathbf{H_2}\uparrow$;
    (4) $FeCl_3 + \mathbf{3NaOH} = \mathbf{Fe(OH)_3}\downarrow + \mathbf{3NaCl}$.
17. (4).
    (1) $MnSO_4 + Na_2S \rightarrow MnS\downarrow + Na_2SO_4$;
    (2) $AgNO_3 + NaCl \rightarrow AgCl\downarrow + NaNO_3$;
    (3) $CuCl_2 + 2NaOH \rightarrow Cu(OH)_2\downarrow + 2NaCl$;
    (4) $FeS + 2HCl \rightarrow FeCl_2 + H_2S\uparrow$.

18. (3).
19. (1). $A^0 + n\bar{e} \rightarrow A^n$.
20. $CaCO_3$; $Ca(OH)_2 + CO_2 = CaCO_3\downarrow + H_2O$.
21. (4). In scheme (b) H_2O_2 is a reductant in an acidic solution, in scheme (d)—in a basic solution.
22. (2).
23. $C + O_2 = CO_2$; $CO_2 + C = 2CO$.
24. $CaH_2 + 2H_2O = Ca(OH)_2 + 2H_2\uparrow$.
25. $2KMnO_4 + 5K_2SO_3 + 3H_2SO_4 = 2MnSO_4 + 6K_2SO_4 + 3H_2O$.
26. (1). $2H^+ + 2\bar{e} \rightarrow H_2$.
27. (2).
28. As and S.
29. $K_2Cr_2O_7 + 14HCl = 2CrCl_3 + 3Cl_2\uparrow + 2KCl + 7H_2O$;
$2KMnO_4 + 5H_2S + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 5S + 8H_2O$.
30. (3). $2KMnO_4 + 16HCl = 2MnCl_2 + 2KCl + 8H_2O + 5Cl_2\uparrow$.
31. (4). $10FeSO_4 + 2KMnO_4 + 8H_2SO_4 = 5Fe_2(SO_4)_3 + 2MnSO_4 + 8H_2O + K_2SO_4$.
32. (2).
33. (3).
34. (1), (4), (5), (6), (7), (8);
(2), (3).
35. (2).
36. +75 (heat released).
37. (4).
Combustion of 12 g of carbon evolved 402.24 kJ of heat
Combustion of x g of carbon evolved 167 600 kJ of heat
$x = 12 \times 167\ 600/402.24 = 5000$ g.
38. (2). 150 — 50 = 100 (kJ) (heat released).
39. (2).
40. (3).
41. (4).
42. (4). The slowest step is rate-determining.
43. $v = k\,[A^2]$. The reaction equation $2A + 3B = 3C + 2D$ describes the overall reaction, and the reaction

rate, as is evident from the experimental data, is dependent on the concentration of substance A to the second power. Hence:

$v = k\,[A]^2 = 0.1^2 = 0.01$ (run I);
$v = k\,[A]^2 = 0.2^2 = 0.04$ (run II);
$v = k\,[A]^2 = 0.2^2 = 0.04$ (run III).

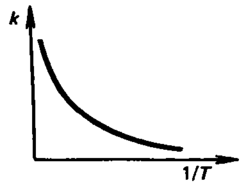
44. (4). Based on the problem data, the rate equation for the process will be: $v_0 = k\,[A_2][B_2]$. If the concentration of each reactant is doubled, the reaction rate will increase four-fold: $v_1 = k\,[2A_2]\,[2B_2] = 4k\,[A_2]\,[B_2] = 4v_0$.
45. (2). The amount of releasing hydrogen is proportional to the net surface of the cubes. The overall surface of zinc increases approximately by a factor of ten. Consequently the volume of the evolving hydrogen increases by a factor of about ten per unit time.
Calculation: let s be the initial surface of the cube, a is the length of its edge, and s' is the surface of a new cube obtained by reducing the size of the initial cube.
Then $s = 6a^2$; $s' = 6a/10^2 = 0.06a^2$ (the length of the new edge is $a/10$); $\sum s' = 1000 \times 0.06 \times a^2 = 60a^2$; hence $\sum s'/s = 60a^2/6a^2 = 10$.
46. (1).
47. (3).
48. (1).
49. (3). MnO_2 catalyzes hydrogen peroxide decomposition according to the net reaction

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2\uparrow.$$

50. (3). The rates of all single-step reactions, or elementary steps, increase with rising temperature. The expression for the rate constant k of the bimolecular reaction (Arrhenius equation) reads: $k = Z \exp \times [E_a/(RT)]$, where Z is a constant; E_a is the activation energy; R, the universal gas constant, and T denotes the absolute temperature.
Thus, the reaction rate grows with temperature exponentially (i.e. it agrees with the plot shown in the

answer (3)). The same dependence can be obtained using the van't Hoff equation. At the end of the nineteenth century, van't Hoff discovered that the reaction rate increases approximately two- or fourfold with a rise in temperature by each 10 degrees.

51.



52. (2).
53. (3). $2^x = 8$, $x = 3$; $2^y = 2$, $y = 1$; $2^z = 4$, $z = 2$.
54. (1). Endothermic reaction.
55. (1) To the left (4) To the right
(2) To the left (5) To the left
(3) To the right
56. (3).
57. (2).
58. $H_2 + I_2 \rightleftharpoons 2HI$; $K_e = \frac{[HI]^2}{[H_2][I_2]}$; (2).

59. (1) $SO_4^{2-} + Ba^{2+} = BaSO_4\downarrow$;
(2) $Al^{3+} + 3OH^- = Al(OH)_3\downarrow$;
(3) $NH_4^+ + OH^- = NH_4OH = NH_3\uparrow + H_2O$;
(4) $Al(OH)_3 + OH^- = [Al(OH)_4]^-$.

60. (1) H_2S (3) $3Fe_3O_4$
(2) $4Zn(NO_3)_2$ (4) SiH_4
61. (4).
62. (1) $2CrO_4^{2-} + 2H^+ = Cr_2O_7^{2-} + H_2O$;
(2) $6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ = 6Fe^{3+} + 2Cr^{3+} + 7H_2O$;
(3) $Cr_2O_7^{2-} + 4Cl^- + 6H^+ = 2CrO_2Cl_2 + 3H_2O$.

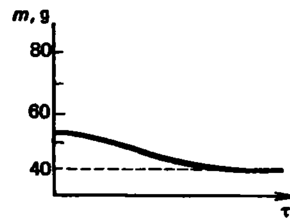
63. (3). Based on the standard oxidation potentials:
$Cu^{2+} + 2\bar{e} = Cu^0$, $E^\circ = +0.34$ V;
$Fe^{3+} + \bar{e} = Fe^{2+}$, $E^\circ = +0.77$ V,
a conclusion can be drawn that the process:
$Fe^{3+} + Cu^0 = Fe^{2+} + Cu^{2+}$
is spontaneous.

64. $CO_3^{2-} + 2H^+ = H_2CO_3 = H_2O + CO_2\uparrow;$
$CO_3^{2-} + H^+ = HCO_3^-.$

65. (1) $CH_4 + 2O_2 = \mathbf{CO_2 + 2H_2O};$
(2) $2H_2S + 3O_2 = \mathbf{2SO_2 + 2H_2O};$
(3) $2PH_3 + 4O_2 = \mathbf{P_2O_5 + 3H_2O}.$

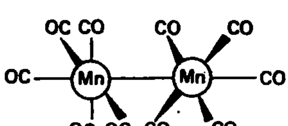
66. $$\underset{107\ \text{g/mole}}{\overset{53.5\ g}{2Fe(OH)_3}} \xrightarrow{T} \underset{160\ \text{g/mole}}{Fe_2O_3} + 3H_2O.$$

$\nu\,(Fe(OH)_3) = 53.5/107 = 0.5$ (mole). The reaction yields 0.25 mole Fe_2O_3, which corresponds to 40 g. On the plot of the sample mass versus the ignition time, we lay off the obtained values of the initial mass (53.5 g) and the mass of the substance (40 g) remained after roasting of iron(III) hydroxide. Since the mass of the iron(III) hydroxide being ignited decreases gradually, we can connect the points corresponding to the initial and final values with a smooth curve.



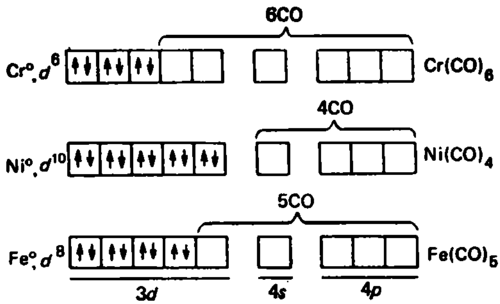
67. (2). No change in the oxidation state of an element occurs during the conversion $O_2 \rightarrow O_3$.

68. (2). *d* Elements with an odd number of valence electrons form two-nucleus complexes of a cluster type with a metal-metal bond. For example, manganese reacts with carbon(II) oxide to yield carbonyl $Mn_2(CO)_{10}$ without bridge groups with the Mn—Mn bond:



Nickel, chromium, and iron, which show an even number of valence electrons, form single-nucleus carbonyls, the carbonyl compositions being in con-

formity with the number of the free orbitals of the atoms of metals:



69. O_3 (gas) + O (gas) = $2O_2$ (gas). Thus, the case under study presents an example of the most simple of homogeneous catalysis, where nitrogen monoxide is a catalyst for the reaction of ozone decomposition, since it increases the rate of the overall reaction but is essentially unaltered in form and amount at the end of the reaction. Nitrogen(II) oxide is consumed only in one step of the reaction ($O_3 + NO = NO_2 + O_2$ (all gases)) and is recovered during the next step ($NO_2 + O = NO + O_2$ (all gases)).

70. (2). The change in mass of a $KClO_3$ sample amounts to about 24-25 g (see the plot).

(1) $4KClO_3 \xrightarrow{\sim 400\ °C} 3KClO_4 + KCl$.

No change of the mass value is observed.

(2) $\underset{122.5\ g/mole}{\overset{0.5\ mole}{2KClO_3}} \xrightarrow{MnO_2} \underset{74.5\ g/mole}{\overset{0.5\ mole}{2KCl}} + 3O_2\uparrow$.

$\nu(KClO_3) = 61.25/122.5 = 0.5$ (mole);

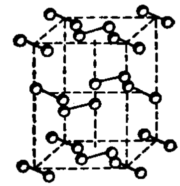
$\nu(KCl) = \nu(KClO_3) = 0.5$ mole.

Change of mass: $61.25 - 0.5 \times 74.5 = 24$ g.

Answer (2) satisfies the plot conditions.

Section 2.1

1.	(1) Gas	Light-green
	(2) Gas	Yellow-green
	(3) Liquid	Red-brown
	(4) Crystals	Dark-violet



2. (2). Halogens in the solid state have a crystal lattice of a molecular type (the figure shows the Br_2 lattice).
3. ns^2np^5.
4. $\underset{\text{pyrolusite}}{MnO_2} + 4HCl = MnCl_2 + 2H_2O + Cl_2\uparrow$.
5. (4).
6. Yellow-green; 3.21; —34.6.
7. (1).
8. (4).
9. (1). Among the halogens, fluorine exhibits the most pronounced oxidative properties. Even such stable substances as water and glass can burn in its atmosphere.
10. (4).
11. (2). The high chemical activity of fluorine can be attributed first to the fact that its molecule has a low dissociation energy (mere 151 kJ/mole); by way of comparison, the dissociation energy of chlorine is 242.5 kJ/mole, and that of oxygen, 498.4 kJ/mole; thus, the chemical bond in most fluorine compounds is strong. Second, the activation energy for reactions involving fluorine is also relatively low.
    The electronegativity of the elements cannot be used as a criterion in deciding on the chemical (oxidizing, in particular) activities of simple substances. Say, nitrogen is one of the most electronegative elements, whereas molecular nitrogen is quite inactive.
12. (4). $SiO_2 + 2F_2 = SiF_4 + O_2$.
13. (4). $Xe + 2F_2 = XeF_4$.
14. $2H_2O + 2F_2 = 4HF + O_2$. This is the main process. However, fluorine-water interaction releases nascent oxygen, which gives rise to a side process:

$$H_2O + F_2 \rightarrow 2HF + O; \quad O + O \rightarrow O_2;$$
$$O + O_2 = O_3; \quad H_2O + O \rightarrow H_2O_2; \quad F_2 + O \rightarrow F_2O$$

yielding two simple substances. But oxygen is formed in a greater amount.

15. ClF_3, chlorine trifluoride; $Cl_2 + 3F_2 = 2ClF_3$.
16. (3).
17. (4). $2HCl + F_2 = 2HF + Cl_2$.
18. (3). $2Cl_2 + 2Ca(OH)_2 = Ca(ClO)_2 + CaCl_2 + 2H_2O$.
19. (1). Calculation:

   (1) $\underset{23\ \text{g/mole}}{Na} + 0.5Cl_2 = NaCl$.

   (2) $\underset{122\ \text{g/mole}}{Sb} + 2.5Cl_2 = SbCl_5$.

   In the case (1), $5/23 = 0.22$ (mole) of sodium is burned to release $0.22Q$ of heat, and in the case (2) only $5/122 = 0.04$ mole of antimony is burned to evolve $0.04Q$ of heat (which is less by a factor of about 5.5).
20. Approximately 32 kPa. Use Mendeleev-Clapeyron equation $PV = (m/M)\ RT$ to find the initial pressure of chlorine at 0 °C: $P = 0.01 \times 8.31 \times 273/(71 \times 0.01) = 32$ (kPa).
21. Around 64 kPa. The calculation is similar to that described for Problem 20.
22. (3).
23. (1).

   $\overset{1\ \text{mole}}{2Na} + \overset{2\ \text{moles}}{Cl_2} = \overset{x\ \text{moles}}{2NaCl}$.

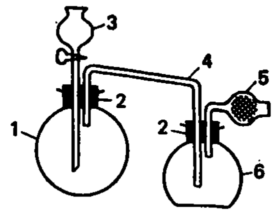
   $\nu\ (NaCl) = 1 \times 2/2 = 1$ mole.
24. (1).
25. (1).

   $\underset{58.5\ \text{g/mole}}{\overset{20\ \text{g}}{NaCl}} + \underset{170\ \text{g/mole}}{\overset{20\ \text{g}}{AgNO_3}} = \underset{143.5\ \text{g/mole}}{AgCl\downarrow} + NaNO_3$.

   $\nu\ (NaCl) = 20/58.5 = 0.34$ (mole);
   $\nu\ (AgNO_3) = 20/170 = 0.117$ mole;
   $m\ (AgCl) = 143.5 \times 0.117 = 16.8$ g.
26. (1).
27. $SiCl_4 + 3HOH = H_2SiO_3 + 4HCl$.
28. (2). A decrease in the heat of the reaction is due to the reduced stability of the forming halogen-hydrogen compounds on passing from fluorine to iodine.
29. Concentrated hydrochloric acid; MnO_2, $KMnO_4$, $K_2Cr_2O_7$ (oxidizing agents).

30. With $KMnO_4$ as an oxidizing agent, the schematic of the apparatus can be drawn in this manner:

(1) round-bottomed flask
(2) rubber plug
(3) dropping funnel
(4) gas-discharge tube
(5) tube filled with activated carbon
(6) flask (for collecting chlorine)



31. (4).
32. (2). $KClO_3 + 6HCl = 3Cl_2\uparrow + KCl + 3H_2O$.
33. (2). NaCl (solid) + H_2SO_4 (conc.) = $NaHSO_4 + HCl\uparrow$.
34. (1). Soda lime is a mixture of slaked lime $Ca(OH)_2$ with NaOH. Hydrogen chloride will react with soda lime.
35. (2).
36. (2).
37. (2).
38. (1).
39. (1).
40. (4).
41. (3). $Na\overset{+1}{Cl}O + 2H\overset{-1}{Cl} = Na\overset{-1}{Cl} + \overset{0}{Cl_2} + H_2O$.
42. 75; 25. $H_2 + Cl_2 = 2HCl$; 30 parts of HCl by volume are produced in the interaction of 15 parts of Cl_2 by volume. Thus, the chlorine percent in the initial gaseous mixture is $60 + 15 = 75\%$ and the hydrogen percent, $10 + 15 = 25\%$.
43. (1) CaF_2 (solid) + H_2SO_4 (conc.) $\rightarrow$
2HF (gas) + $CaSO_4$;
(2) 2NaCl (solid) + H_2SO_4 (conc.) $\rightarrow$
2HCl (gas) + Na_2SO_4;
(3) 2NaBr (solid) + $2H_2SO_4$ (conc.) $\xrightarrow{T}$
Br_2 (gas) + SO_2 (gas) + Na_2SO_4 + $2H_2O$;
(4) 8NaI (solid) + $5H_2SO_4$ (conc.) $\xrightarrow{T}$
$4Na_2SO_4$ + H_2S (gas) + $4I_2$ + $4H_2O$.

HBr and HI cannot be produced in the reactions between their salts and H_2SO_4, since they undergo

oxidation in the presence of sulphuric acid at elevated temperature required for initiating reactions (3) and (4).

44. $Zn + 2HCl = ZnCl_2 + H_2\uparrow$. In this reaction equation hydrochloric acid acts as an oxidizing agent as a result of the reduction of hydrogen ions:

$(2H^+ + 2\bar{e} \rightarrow H_2^0)$.

45. (4).

$$\underset{65\ \text{g/mole}}{\overset{13\ \text{g}}{Zn}} + \overset{11.2\ \text{litres}}{2HCl} = ZnCl_2 + H_2\uparrow.$$

$\nu(Zn) = 13/65 = 0.2$ mole;
$\nu(HCl) = 11.2/22.4 = 0.5$ mole.
Since zinc is in a deficit, 0.2 mole, i.e. 4.48 litres of H_2, was released.

46. HClO. Can be attributed to the lowest stability of the anion and, in addition, to the crucial role of nascent oxygen evolved on decomposition of hypochlorous acid in the light.

47. $3Cl_2 + 6KOH = 5KCl + KClO_3 + 3H_2O$; on heating.

48. 0.672.

$$\underset{122.5\ \text{g/mole}}{\overset{2.45\ \text{g}}{2KClO_3}} = 2KCl + 3O_2\uparrow.$$

$\nu(KClO_3) = 2.45/122.5 = 0.02$ mole;
$\nu(O_2) = 0.03$ mole; $V(O_2) = 0.03 \times 22.4 =$ 0.672 litre.

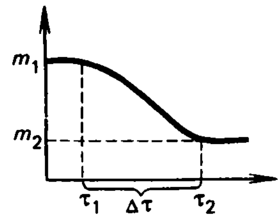
49. (1) $4HCl + MnO_2 \xrightarrow{T} MnCl_2 + Cl_2\uparrow + 2H_2O$;
(2) $Cl_2 + H_2 \xrightarrow{h\nu} 2HCl$;
(3) $3Cl_2 + 6KOH \xrightarrow[\text{hot}]{T} KClO_3 + 5KCl + 3H_2O$;
(4) $KClO_3 + 6HCl = 3Cl_2\uparrow + KCl + 3H_2O$.

50. (3).

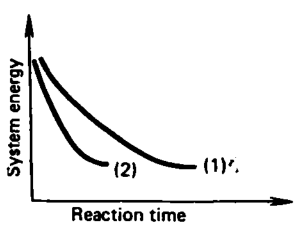
$$\underset{122.5\ \text{g/mole}}{2KClO_3} \xrightarrow{T} \underset{74.5\ \text{g/mole}}{2KCl} + 3O_2\uparrow.$$

According to the equation for the reaction of thermal decomposition of 1 mole of Berthollet's salt, the residue mass is one and a half times less than the

initial mass (122.5/74.5 = 1.64). The oxygen gas volatalizes. Thus, if we mark, on the plot, the initial mass of Berthollet's salt as m_1 and the mass remained after the decomposition as m_2, the curve on the plot will reflect thermal decomposition during a certain time period ($\Delta\tau$) accompanied by a decrease in mass. After complete decomposition of the salt the remained mass will not change, since potassium chloride formed in the reaction fails to decompose on heating.



51. (2). The radical Cl• is involved in further interaction.
52. $v = k_1$ [HBr] [O_2]. The overall rate of the process is determined by the slowest step.
53. (2). Oxygen difluoride OF_2 is a strong oxidizing agent. It is obtained by passing fluorine rapidly through a dilute alkaline solution:
$2F_2 + 2NaOH\ (sln) = OF_2 + 2NaF + H_2O.$
54. (4).
55.



56. (2). Iodine is a weaker oxidant than bromine.
57. (4).
58. (3).
59. (1) $K_1 = [I_2\ (sln)]$;

(2) $K_2 = \frac{[I_3^-]}{[I^-]}$;

(3) $K_3 = \frac{[I_3^-]}{[I^-][I_2]}$;

(b).

60. $I_2 + 10HNO_3\ (conc.) = 2HIO_3 + 10NO_2\uparrow + 4H_2O.$

Section 2.2

1. ns^2np^4.
2. (2); (1).
3. $^{18}_{8}O$ $1s^22s^2p^4$; $^{16}_{8}O$ $1s^22s^2p^4$.
4. (4). $\overset{+1}{O_2}\overset{-1}{F_2}$.
5. (2). $m = 50 \times 1 \times 32/22.4 = 71.4$ (g).
6. (2). $p(O_2) = 98.66 \times 210/(210 + 780 + 10) = 20.72$ (kPa).
7. (4).
8. (1). $p(O_2) = 800 \times 2/(2 + 3) = 320$ (kPa).
9. (2). Samples weighing 10 g each.

$$\underset{216.6\ \text{g/mole}}{\overset{0.05\ \text{mole}}{2HgO}} \xrightarrow{T} 2Hg + \overset{0.025\ \text{mole}}{O_2}\uparrow.$$

$$\underset{122.5\ \text{g/mole}}{\overset{0.08\ \text{mole}}{2KClO_3}} \xrightarrow{MnO_2,\ T} 2KCl + \overset{0.12\ \text{mole}}{3O_2}.$$

$$\underset{158\ \text{g/mole}}{\overset{0.06\ \text{mole}}{2KMnO_4}} \rightarrow K_2MnO_4 + MnO_2 + \overset{0.03\ \text{mole}}{O_2}\uparrow.$$

$$\underset{101\ \text{g/mole}}{\overset{0.1\ \text{mole}}{2KNO_3}} \rightarrow 2KNO_2 + \overset{0.05\ \text{mole}}{O_2}\uparrow.$$

10. (2). The alkali metals burn in the air (or in oxygen under atmospheric pressure). In the process, lithium forms only the Li_2O oxide (with traces of Li_2O_2), sodium commonly forms the Na_2O_2 peroxide, but on heating and under a high oxygen pressure it can absorb more oxygen and form the NaO_2 superoxide. Potassium, rubidium, and cesium form superoxides of KO_2 type.
    Sodium oxide Na_2O is commonly produced by reducing Na_2O_2 with metallic sodium (i.e. by the indirect method):
    $Na_2O_2 + 2Na = 2Na_2O$.
11. (4).
12. (2); $3O_2 \overset{\text{ϟ}}{=} 2O_3$.
13. $2KI + O_3 + H_2O = I_2 + 2KO$ [illegible] $)_2\uparrow$.

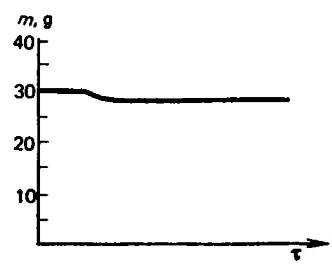
14. Equation for the reaction of potassium permanganate decomposition:

$$2KMnO_4 \xrightarrow{T} K_2MnO_4 + MnO_2 + O_2\uparrow.$$

The sample mass will decrease by the mass of the oxygen evolved during its decomposition, that is:

2×158 g $KMnO_4$ evolves 16 g O_2
30 g $KMnO_4$ evolves x g
$x = 30 \times 16/(2 \times 158) = 1.5$ (g) O_2.

We now construct a plot of the sample mass as a function of the ignition time.



15. (1). Substances whose molecules contain unpaired electrons possess their own magnetic field and are *paramagnetic*. Such substances are drawn into the magnetic field.

16. 6000.
Melting of 1 g H_2O at 0 °C requires 333.5 J of heat
Melting of 18 g $\underset{\text{(1 mole of ice)}}{H_2O}$ at 0 °C requires q J of heat
$q = 6000$ J/mole.

17. (2).
18. (4).
19. (4).

$$\underset{88\text{ g/mole}}{\overset{11\text{ g}}{FeS}} + \underset{36.5\text{ g/mole}}{\overset{m,\text{ g}}{2HCl}} = FeCl_2 + H_2S\uparrow.$$

ν (FeS) $= 11/88 = 0.125$ (mole), according to the reaction equation ν (HCl) $= 0.25$ (mole). Then m (HCl) $= 0.25 \times 36.5 = 9.12$ (g); m (sln) $= m$ (HCl)/ω (HCl) $= 9.12/0.2 = 45.6$ (g).

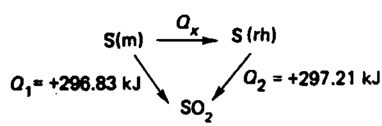
20. (2). $2HgO \xrightarrow{T} 2Hg + O_2\uparrow$.
21. (2).

22. Reduces.
23. (2); (b).

Oxide	δ	*Oxide*	δ
Na_2O	-0.81	P_2O_5	-0.13
MgO	-0.35	SO_3	-0.06
Al_2O_3	-0.31	Cl_2O_7	-0.01
SiO_2	-0.23		

24. (4).
25. (3).
26. (2).
27. (2).
28. (1).
29. (3).
30. Increase; decrease. $2SO_2 + O_2 \rightleftharpoons 2SO_3 + Q$.
31. (3).
32. (3). $Pb^{2+} + H_2S = PbS\downarrow + 2H^+$.
33. (2). $+296.9 + 101.3 = 398.2$ (kJ).
34. —0.38.

$$S\ (m) + O_2 \rightarrow SO_2 + 296.83\ \text{kJ},$$
$$S\ (rh) + O_2 \rightarrow SO_2 + 297.21\ \text{kJ}.$$



$$Q_x = +296.83 - 297.21 = -0.38\ \text{(kJ)}.$$

35. (2).
36. (1).
37. (2).
38. Copper(I) sulphide.
39. Copper, concentrated sulphuric acid

$$(Cu + 2H_2SO_4 \overset{T}{=} CuSO_4 + SO_2\uparrow + 2H_2O);$$

sulphite with acid

$$(2H^+ + SO_3^{2-} = SO_2\uparrow + H_2O).$$

40. (2).
41. (2). $M(H_2S) = 34$ g/mole; $m(H_2S) = 2.3 \times 34/22.4 \approx$ 3.5 g; $\omega(H_2S) = 3.5 \times 100/1003.5 = 0.34$ (%).

42. $2FeCl_3 + H_2S \rightarrow 2FeCl_2 + 2HCl + S$;
$Fe^{3+} + \bar{e} \rightarrow Fe^{2+}$; $H_2S - 2\bar{e} \rightarrow S + 2H^+$.

43. $3S + 6NaOH = 2Na_2S + Na_2SO_3 + 3H_2O$.

44. (3).

45. (4).

46. (2). The reaction equation:

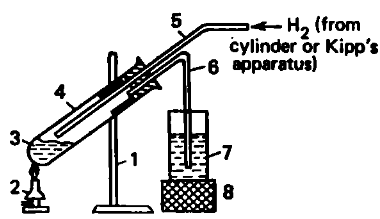
$$\underset{98\text{ g/mole}}{\overset{245\text{ g}}{2H_2SO_4}} + Zn = ZnSO_4 + \underset{64\text{ g/mole}}{SO_2\uparrow} + 2H_2O.$$

$\nu(H_2SO_4) = 245/98 = 2.5$ (mole). According to the reaction equation $\nu(SO_2) = 1.25$ mole; hence $m(SO_2) = 64 \times 1.25 = 80$ (g).

47. (1) $Zn + H_2SO_4 = ZnSO_4 + H_2\uparrow$;
(2) $Na_2CO_3 + H_2SO_4 = Na_2SO_4 + CO_2 + H_2O$;
(3) $5Na_2SO_3 + 2KMnO_4 + 3H_2SO_4 = 5Na_2SO_4 + 2MnSO_4 + K_2SO_4 + 3H_2O$.

48.

(1) stand
(2) gas burner
(3) molten sulphur
(4) test tube with a plug
(5) tube for hydrogen supply
(6) tube for removal of hydrogen sulphide
(7) beaker with water to absorb hydrogen sulphide
(8) wooden block



49. (2).

50. (4).

$$\overset{x\text{ moles}}{H_2S} + 1.5O_2 = \overset{(18x)\text{ g}}{H_2O} + \overset{(64x)\text{ g}}{SO_2}.$$

$$\overset{(64x)\text{ g}}{SO_2} + H_2O = \overset{(82x)\text{ g}}{H_2SO_3}.$$

m (sln) $= (82x + 49.2)$ g; $\omega(H_2SO_3) = m(H_2SO_3)/$ $/m$ (sln); $0.0164 = 82x/(82x + 49.2)$, hence $x = 0.01$, i.e. $\nu(H_2S) = 0.01$ mole, which makes 0.22 litre. Since at STP the mixture volume was 1.5 litres, the oxygen volume is 1.28 litres.

51. (3). $H_2S + 1.5O_2 = H_2O + SO_2$.
$Q_{reaction} = +297 + 286 - 21 = +562$ (kJ).

52. (4); $Pb^{2+} + 2NO_3^- + 2NH_4^+ + S^{2-} = PbS$ (solid) $+ 2NH_4^+ + 2NO_3^-$.

53. $3CuS + 8HNO_3 = 3Cu(NO_3)_2 + 3S + 2NO + 4H_2O$.

54. (3).

$$\underset{2\text{ moles}}{2Cu} + \underset{1\text{ mole}}{S} = \underset{1\text{ mole}}{Cu_2S}.$$

$\nu(Cu) = 12.7/64.5 = 0.2$ (mole); $\nu(S) = 3.0/32 = 0.09$ (mole). 0.09 mole S and 0.18 mole Cu react according to the reaction equation, which means that copper is in the excess.

55. (1) $2KMnO_4 + 5H_2SO_3 = 2MnSO_4 + K_2SO_4 + 3H_2O + 2H_2SO_4$;
(2) $K_2Cr_2O_7 + 3H_2SO_3 + H_2SO_4 = Cr_2(SO_4)_3 + 4H_2O + K_2SO_4$;
(3) $Hg_2(NO_3)_2 + H_2SO_3 + H_2O = 2Hg\downarrow + 2HNO_3 + H_2SO_4$.

56. (1).

$$\underset{0.1\text{ mole}}{Fe} + S = \underset{0.1\text{ mole}}{FeS} \text{ (a);}$$

$$\underset{0.1\text{ mole}}{FeS} + 2HCl = FeCl_2 + \underset{0.1\text{ mole}}{H_2S\uparrow} \text{ (b);}$$

$$Fe + 2HCl = FeCl_2 + H_2\uparrow \text{ (c);}$$

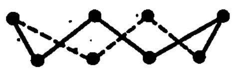
$$Pb(NO_3)_2 + H_2S = \underset{239\text{ g/mole}}{PbS\downarrow} + 2HNO_3 \text{ (d).}$$

$\nu(H_2S) = \nu(PbS) = 23.9/239 = 0.1$ (mole) (equations b and d).
ν (gases) $= 4.48/22.4 = 0.2$ (mole). Consequently, in the mixture of the evolved gases $\nu(H_2) = 0.1$ mole (equation c).
Since hydrochloric acid dissolved the mixture completely, all of the sulphur has entered into the reaction (a), i.e. the iron excess is 0.1 mole (equation c). This indicates that the initial mixture contained 0.2 mole of iron (11.2 g) and 0.1 mole of sulphur (3.2 g).

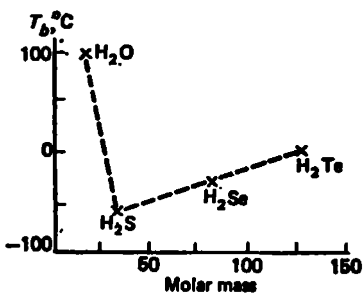
57. (4). CdS, yellow precipitate.

58. (1).

59. $H_2S + 4Br_2 + 4H_2O = H_2SO_4 + 8HBr$.
60. (3). Hydrolysis: $Na_2S + HOH \rightleftharpoons NaHS + NaOH$.
(basic medium)
61. (2). $2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$.
62. (4). S_8, cyclic molecules having the shape of a crown:



63. (3). $SF_4 + 3H_2O = H_2SO_3 + 4HF$.
64. (2). $SO_2 + Cl_2 \xrightarrow{h\nu} SO_2Cl_2$.
65. (1).
66. (2).
67. Weaken.
68.



Hydride	T_b, °C
H_2O	100
H_2S	−60.3
H_2Se	−41.4
H_2Te	−2

69. Na_2SeO_4 (sodium selenate); NaCl (sodium chloride). $Na_2SeO_3 + Cl_2 + 2NaOH = Na_2SeO_4 + 2NaCl + H_2O$.
70. (1).
71. (1) $Se + H_2 = H_2Se$;
(2) $H_2Se + Ca = CaSe + H_2$;
(3) $2H_2Se + 3O_2 = 2SeO_2 + 2H_2O$;
(4) $H_2Se + NaOH = NaHSe + H_2O$.
72. $Na_2S_2O_3$; $Na_2SO_3 + S \xrightarrow{T} Na_2S_2O_3$.
73. $AgCl + 2Na_2S_2O_3 = Na_3[Ag(S_2O_3)_2] + NaCl$.
74. (3).

$FeS + 2HCl = FeCl_2 + H_2S\uparrow$;

$Fe + 2HCl = FeCl_2 + H_2\uparrow$.
$m(Fe) = 5 \times 0.05 = 0.25$ (g), $m(FeS) = 4.75$ g.
$V(H_2S) = 4.75 \times 22.4/88 = 1.21$ (litre),
$V(H_2) = 0.25 \times 22.4/56 = 0.1$ (litre).

75. (4).
76. (2).
77. (2).
78. (3).
79. $CaSeO_3$; K_2TeO_3.
80. (3).
81. (3).

$$\overset{0.5\ \text{mole}}{2MS} + 3O_2 = 2MO + \overset{0.5\ \text{mole}}{2SO_2}.$$

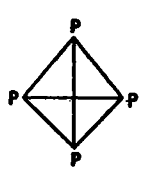
$$\overset{0.5\ \text{mole}}{SO_2} + 2H_2O + \underset{254\ \text{g/mole}}{\overset{0.5\ \text{mole}}{I_2}} = H_2SO_4 + 2HI.$$

$\nu\,(I_2) = 127/254 = 0.5$ (mole).

48.5 g MS forms 0.5 mole SO_2
$(2A + 64)$ g MS forms 2 moles SO_2
Hence $A = 65$, which suggests zinc metal.

Section 2.3

1. ns^2p^3.
2. (1) Bi; (2) As; (3) N; (4) Sb; (5) P.
3. (2).
4. (1).
5. (3).
6. (2). P_4 molecule geometry:



7. (4).
8. (2).
9. $Ca_3P_2 + 6H_2O = 3Ca(OH)_2 + 2PH_3\uparrow$.

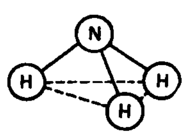
10. (2).

$$N_2 + 3H_2 \rightleftharpoons 2NH_3\uparrow.$$

	N_2	H_2	NH_3
Initial conditions	15 (litres)	15 (litres)	x (litres)
With 100% yield of NH_3	5 (litres)	15 (litres)	10 (litres)
With 50% yield of NH_3	2.5 (litres)	7.5 (litres)	5 (litres)

After the reaction the volumes of the gases are:
$V(N_2) = 15 - 2.5 = 12.5$ (litres),
$V(H_2) = 15 - 7.5 = 7.5$ (litres);
$V(NH_3) = 5$ litres.

11. $2NH_4Cl + Ca(OH)_2 \overset{T}{=} 2NH_3\uparrow + CaCl_2 + 2H_2O$.
12. (2).
13. (3).
14. $O_2 + h\nu \rightarrow \cdot O \cdot + \cdot O \cdot$; $\cdot O \cdot + N_2 \rightarrow NO + \cdot\dot{N}\cdot$;
$\cdot\dot{N}\cdot + O_2 \rightarrow NO + \cdot O \cdot$, etc.
The activation energy of NO synthesis is high; the formation occurs by a chain reaction.
15. (1).
16. (4). The shape of the NH_3 molecule can be represented as:



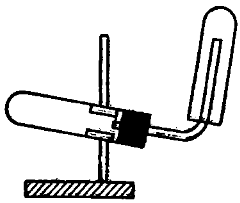
17. (3).
18. (4).
19. (4). $2AgNO_3 \xrightarrow{T} 2Ag + 2NO_2\uparrow + O_2\uparrow$.
20. (1).
21. (4).
22. (4). $2Ca(OH)_2 + 4NO_2 = Ca(NO_2)_2 + Ca(NO_3)_2 + 2H_2O$.
23. N_2; $4NH_3 + 3O_2 \xrightarrow{T} 2N_2 + 6H_2O$.
24. NO; $4NH_3 + 5O_2 \xrightarrow{\text{catalyst}} 4NO + 6H_2O$.

25. (3). Oxidation state of nitrogen in $NaNO_2$ is +3.
26. I_2, NO; $\underset{\text{(oxidant)}}{2NaNO_2} + 2KI + 2H_2SO_4 =$
$I_2 + 2NO + Na_2SO_4 + K_2SO_4 + 2H_2O$.
27. Mn^{2+}, NO_3^-, $\underset{\text{(reductant)}}{5NaNO_2} + 2KMnO_4 + 3H_2SO_4 =$
$2MnSO_4 + 5NaNO_3 + K_2SO_4 + 3H_2O$.
28. (3).
29. (2), (3), and (4); $Ba(OH)_2$ (exhibits acidic properties); C and HCl (oxidative).
30. (3).
31. (1). $Cu + \underset{\text{(conc.)}}{4HNO_3} = Cu(NO_3)_2 + 2NO_2 + 2H_2O$.
32. (4). $4Mg + \underset{\text{(very dilute)}}{10HNO_3} = 4Mg(NO_3)_2 +$
$NH_4NO_3 + 3H_2O$.
NH_4NO_3 is formed in the interaction:
$NH_3 + HNO_3 = NH_4NO_3$.
33. (1). In accordance with Le Chatelier's principle, the equilibrium shifts to the right when the system is cooled. Therefore liquid nitrogen(IV) oxide mainly consists of N_2O_4.
34. $3P + 5HNO_3 + 2H_2O = 3H_3PO_4 + 5NO$.
35. HNO_3, HCl; $Au + HNO_3 + 3HCl =$
$AuCl_3 + NO\uparrow + 2H_2O$.
36. $V = k\,(p\,(NO))^2\,p\,(Cl_2)$.
37. (4). It should be borne in mind that the chemical reaction characterizes only the chemical process and the material balance, the mechanism and the rate of the reaction do not follow from the reaction equation.
38. (2). Approximately in 6 or 6.5 minutes; the problem can be solved by plotting the N_2O_5 concentration as a function of time using the experimental data given in the problem.
39. (2). $5H_2SO_4 + 2P = 2H_3PO_4 + 2H_2O + 5SO_2\uparrow$.
40. $2KNO_3 + 3C + S = N_2\uparrow + 3CO_2\uparrow + K_2S + Q$.
41. (1). $pV = \nu RT$; $\nu = 233 \times 0.026/(8.31 \times 300) = 2.43 \times 10^{-3}$ (mole).
42. $v = k_1\,[\cdot NO_3]$. This is associated with the fact that the slowest step is rate-determining for the overall process. The process rate can be expressed in this

manner: $v = k\,[N_2O_5]$, since equation (a) reflects the equilibrium between N_2O_5 and NO_3.

43. $NF_3 + 3H_2O = HNO_2 + 3HF$;
$NCl_3 + 3H_2O = NH_3 + 3HOCl$.

44. (1);



45. (2); $Ca_3(PO_4)_2 + 3H_2SO_4 = 2H_3PO_4 + 3CaSO_4\downarrow$.

46. (2).

$$\underset{310\ \text{g/mole}}{\overset{3.1\ \text{kg}}{Ca_3(PO_4)_2}} + 5C + 3SiO_2 = 3CaSiO_3 + \underset{31\ \text{g/mole}}{2P} + 5CO\uparrow.$$

$\nu\,(Ca_3(PO_4)_2) = 3100/310 = 10$ (moles);
$\nu\,(P) = 20$ moles (from the reaction).
$m\,(P) = 31 \times 20 = 620$ (g).

47. (3). $M_r\,(P) = 31$; $M_r\,(Na_2HPO_4) = 142$;
$M_r\,(H_2O) = 18$; $M_r\,(Na_2HPO_4 \cdot nH_2O) = 142 + 18n$;
$(142 + 18n) \times 0.1156 = 31$; $n = 7$.

48. (2). Ammonium nitrate NH_4NO_3 contains nitrogen atoms exhibiting different oxidation states, i.e. -3 and $+5$. The anion of this salt shows pronounced oxidative properties, and the cation, reductive properties. Therefore, on heating, a redox reaction occurs during which the ammonium ion is oxidized and the nitrate ion is reduced. These redox reactions are called the *reactions of intramolecular oxidation-reduction.*

On heating, this salt decomposes irreversibly with the formation of a product containing nitrogen in

the intermediate oxidation state:

$$\overset{-3}{N}H_4\overset{+5}{N}O_3 = \overset{+1}{N_2}O + 2H_2O.$$

All the other salts listed in the problem contain nitrogen exhibiting a single value of the oxidation state.

49. (3). H_3PO_4 mass in the initial solution: $m\ (H_3PO_4) = 250 \times 0.098 = 24.5$ (g).
The mass of phosphoric acid formed in the reaction $3H_2O + P_2O_5 = 2H_3PO_4$ can be found from the proportion
142 g P_2O_5 forms 196 g H_3PO_4
14.2 g P_2O_5 forms x g H_3PO_4
$x = 19.6$ g H_3PO_4.
The mass of the final solution is: $250 + 14.2 = 264.2$ (g). The overall mass of phosphoric acid in solution: $24.5 + 19.6 = 44.1$ (g). The mass percent of H_3PO_4 in the obtained solution:
$\omega\ (H_3PO_4) = 44.1 \times 100/264.2 = 16.7$ (%).

50. (1) $Ca_3(PO_4)_2$;
(2) $Ca(H_2PO_4)_2 + 2CaSO_4$;
(3) $Ca(H_2PO_4)_2$;
(4) $CaHPO_4 \cdot 2H_2O$;
$Ca(H_2PO_4)_2$ is double superphosphate.

51. $Ca_5(PO_4)_3F$. The general composition of apatite can be represented as: $Ca_a:P_b:O_c:F_d$. Then $40a:31b:16c:19d = 39.7:18.4:38.1:3.8$. Whence $a:b:c:d = 0.99:0.59:2.38:0.20$. Substituting the ratio of integers for the ratio of fractions we obtain: $a:b:c:d = 5:3:12:1$. Thus, the apatite formula reads: $Ca_5P_3O_{12}F$ or $Ca_5(PO_4)_3F$.

52. (1).
$$\underset{132\ \text{g/mole}}{(NH_4)_2SO_4} + 2NaOH = 2NH_3\uparrow + 2H_2O + Na_2SO_4.$$
$\nu(NH_3) = 2\nu(NH_4)_2SO_4 = 3.96/132 = 0.03$ (mole);
$\nu(H_3PO_4) = 5.88/98 = 0.06$ mole;
$\nu(NH_3) : \nu(H_3PO_4) = 0.03:0.06 = 1 : 2$.
The calculation shows that phosphoric acid is in a greater excess, and the reaction goes according to the equation:

$$NH_3 + H_3PO_4 = NH_4H_2PO_4.$$

53. $6P + 5KClO_3 = 5KCl + 3P_2O_5$. A mixture of red phosphorus and Berthollet's salt is formed when we light a match by striking the tip of a match against a side surface of a matchbox, which contains finely ground red phosphorus. Berthollet's salt, however, is not in the finely ground state and it should be ground. Glass, which is harder than Berthollet's salt, does this job. In addition, glass particles are needed because reaction chain termination processes take place on the glass surface, the reaction chains being initiated through friction (by scratching a match against a matchbox), and phosphorus combustion does not propagate beyond the boundary left by the match on the box.
The tip of a match also contains sulphur (a flammable material). Thus, the process of the match ignition includes these three consecutive reactions:
(1) bursting into flame of a phosphorus-Berthollet's salt mixture caused by striking a match;
(2) inflammation of the mixture contained in the tip of a match;
(3) ignition of the match.

54. (4); $CO_2 + 2NH_3 = CO(NH_2)_2 + H_2O$.

55. $(NH_4)_2Cr_2O_7 \xrightarrow{T} N_2\uparrow + Cr_2O_3 + 4H_2O\uparrow$.

56. (1).
$P\text{ (gas)} + 1.5Cl_2\text{ (gas)} = PCl_3\text{ (gas)} + 280\text{ kJ};$
$P\text{ (gas)} + 2.5Cl_2\text{ (gas)} = PCl_5\text{ (gas)} + 367\text{ kJ};$
$PCl_3\text{ (gas)} + Cl_2\text{ (gas)} = PCl_5\text{ (gas)} + Q\text{ kJ}.$
$Q = 367 - 280 = 87\text{ (kJ)}.$

57. (1).

58. (3); (1).

59. (4). $3\overset{0}{As} + 5HNO_3 + 2H_2O = 3H_3\overset{+5}{As}O_4 + 5NO$.

60. (1). $\overset{0}{Bi} + 4HNO_3 = \overset{+3}{Bi}(NO_3)_3 + NO + 2H_2O$.

61. (4).

$$\underset{\approx 1.2\text{ mole}}{2NaNO_3} = 2NaNO_2 + \underset{0.6\text{ mole}}{O_2\uparrow}.$$

$$\underset{\approx 0.3\text{ mole}}{2Pb(NO_3)_2} = 2PbO + \underbrace{\underset{0.6\text{ mole}}{4NO_2\uparrow} + \underset{0.15\text{ mole}}{O_2\uparrow}}_{0.75\text{ mole}}.$$

$$\underset{0.6\text{ mole}}{2AgNO_3} = Ag + \underbrace{\underset{0.6\text{ mole}}{2NO_2\uparrow} + \underset{0.3\text{ mole}}{O_2}}_{0.9\text{ mole}}.$$

$$\underset{1.25\text{ mole}}{NH_4NO_3} = \underset{1.25\text{ mole}}{N_2O\uparrow} + 2H_2O.$$

62. NH_4Cl, $NaNO_2$;

$$\underset{(sat.)}{NH_4Cl} + \underset{(sat.)}{NaNO_2} \overset{T}{=} NH_4NO_2 + NaCl;$$

$$NH_4NO_2 \xrightarrow{T} N_2 + 2H_2O.$$

63. (4). $PCl_5 + 4H_2O = H_3PO_4 + 5HCl$.
64. (3). $4HNO_3 = 2H_2O + 4NO_2\uparrow + O_2\uparrow$.
65. $HNO_3 + 3HCl = NOCl\uparrow + Cl_2\uparrow + 2H_2O$.
66. (4). $N_2O_3 + 2NaOH = 2NaNO_2 + H_2O$.
67. (3). $M\ (P_2O_5) = 142$ g/mole, i.e. $\nu\ (P_2O_5) = 1$ mole

$$P_2O_5 + 3H_2O = \underset{98\text{ g/mole}}{2H_3PO_4}.$$

The initial mass of orthophosphoric acid is: $500 \times 10/100 = 50$ (g). The mass of orthophosphoric acid after dissolution of 1 mole of P_2O_5 amounts to: $50 + 2 \times 98 = 246$ (g).
Mass of H_3PO_4 solution: $500 + 142 = 642$ (g).
Mass percent of H_3PO_4 in the solution obtained is: $246 \times 100/642 = 38.3$ (%).

68. (1) $N_2 + 3H_2 \rightleftarrows 2NH_3$;
(2) $4NH_3 + 5O_2 \xrightarrow{\text{catalyst}} 4NO + 6H_2O$;
(3) $2NO + O_2 = 2NO_2$;
(4) $4NO_2 + 2H_2O + O_2 = 4HNO_3$;
(5) $NH_3 + HNO_3 = NH_4NO_3$.

69. (1) $2P + 3Mg \xrightarrow{T} Mg_3P_2$;
(2) $Mg_3P_2 + 6H_2O = 3Mg(OH)_2 + 2PH_3\uparrow$;
(3) $2PH_3 + 4O_2 = P_2O_5 + 3H_2O$;
(4) $P_2O_5 + 3H_2O = 2H_3PO_4$;
(5) $3Ca(OH)_2 + 2H_3PO_4 = Ca_3(PO_4)_2\downarrow + 6H_2O$;
(6) $Ca_3(PO_4)_2 + 2H_2SO_4 = Ca(H_2PO_4)_2 + 2CaSO_4\downarrow$.

70. (1) $N_2 + O_2 = 2NO$; $2NO + O_2 = 2NO_2$;
$2NO_2 + H_2O = HNO_3 + HNO_2$;
$2HNO_3 + Ca(OH)_2 = Ca(NO_3)_2 + 2H_2O$;

(2) nutrition and growth of plants;
(3) decomposition of plant and animal remnants;
(4) nutrition and growth of plants;
(5) bacterial ammonia oxidation
$4NH_3 + 5O_2 = 4NO + 6H_2O$;
industrial oxidation of ammonia—production of HNO_3 and its salts:

$NO \rightarrow NO_2 \rightarrow HNO_3 \rightarrow NH_4NO_3$;

(6) (a) manufacture of ammonia;
(b) activity of nitrogen-fixing bacteria;

$2N_2 + 6H_2O + 3C = 4NH_3 + 3CO_2$;

(c) rhizobia activity;

(7) combustion of plant substances;
(8) explosions; bacteria activity; denitrification;
(9) bacteria activity, ammonia oxidation to free nitrogen.

Section 2.4

1. ns^2np^2.
2. (2).
3. (1) Coordination sp^3
   (2) Layered sp^2
   (3) Linear sp
4. (4).
5. (3).
6. (3); (c).
7. (3); (c).
8. (2).
9. (2). Subtract equation (b) from equation (a). Further we have:

$$C\ (\text{diamond}) + O_2 - O_2 = CO_2 - CO_2 + C\ (\text{graphite}) + 395.5 - 393.4;$$
$$C\ (\text{diamond}) = C\ (\text{graphite}) + 2.1\ \text{kJ/mole}.$$

10. (3). $SiH_4 + 2O_2 = SiO_2 + 2H_2O$.

$$Q_{\text{reaction}} = +908 + 2 \times 241.8 - (-35 + 2 \times 0) = 1426.6\ \text{kJ/mole}.$$

11. (3). $Al_4C_3 + 12H_2O = 4Al(OH)_3 + 3CH_4\uparrow$.
12. $^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$.
13. (2). The intensity of the decay of carbon-14 isotope will decrease twice in 5600 years, four times in 11 200 years, eight times in 16 800 years, and 10 times in 18 200 years: 16 800 + 5 600 × 1/4.
14. (2). $\lambda = \ln 2/\tau_{\frac{1}{2}}$; $t = \left(\tau_{\frac{1}{2}}/\ln 2\right) \ln (N_0/N) =$

    $(5730/0.693) \ln (13.6/12.0) = 1035$ years old; the tree was cut in $1983 - 1035 = 948$.
15. (3). $t = \left(\tau_{\frac{1}{2}}/\ln 2\right) \ln (N_0/N)$.

    For $N_0/N = 13.6/12.0$ we have 1035 years
    For $N_0/N = 13.6/12.2$ we have 898 years
    For $N_0/N = 13.6/11.8$ we have 1174 years
    Thus, the tree (see Problem 14) was cut: 1035 (+139/—137) years ago.
16. (2).

$$\underset{0.5\text{ mole}}{2Mg} + \underset{0.2\text{ mole}}{SiO_2} = \underset{0.4\text{ mole}}{2MgO} + \underset{0.2\text{ mole}}{Si}.$$

$\nu\,(Mg) = 12/24 = 0.5$ mole;
$\nu\,(SiO_2) = 12/60 = 0.2$ mole.

$$\underset{\text{(excess)}}{\overset{0.1\text{ mole}}{2Mg}} + \overset{0.05\text{ mole}}{Si} = \overset{0.05\text{ mole}}{Mg_2Si}.$$

Thus; $\nu\,(Si) = 0.2 - 0.05 = 0.15$ mole;
$\nu\,(MgO) = 0.4$ mole; $\nu\,(Mg_2Si) = 0.05$ mole.

17. (1). In the equilibrium:

    $CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^-$, pH below 7.
18. (4).
19. $SiH_4 + 2O_2 = \underset{\text{(sand)}}{SiO_2} + \underset{\text{(water)}}{2H_2O}$.
20. (2). $CaCO_3 + H_2SO_4 = CaSO_4\downarrow + CO_2 + H_2O$. However, $CaSO_4$ is sparingly soluble in water and precipitates on the surfaces of marble chunks with which the acid ceases to react.
21. (1).
22. (2). On the strength of Le Chatelier's principle.

Henry-Louis Le Chatelier (1850-1936). The French physicochemist. Was named professor of chemistry at the École des Mines (1877-1919), College des France (1898-1907), University of Paris (1908-1925). Member of Paris Academy of Sciences (1907). He became an authority on metallurgy, cements, glasses, fuels, and explosives, and his interests turned to the study of heat. He developed a platinum and rhodium thermocouple for measuring high temperatures and an optical pyrometer which measures intense heat by analysing the light from the heat source. Le Chatelier first enunciated his principle in 1884 and dealt with the effect of changing pressures and other conditions in his *Law of Stability of Chemical Equilibrium*. He was an honorary member of the USSR Academy of Sciences (1927).

23. (1).

24. SiO_2; CaC_2; $5SiO_2 + 2CaC_2 = 5Si + 2CaO + 4CO_2\uparrow$.

25. $\omega(CO) = 38.89$, $\omega(CO_2) = 61.11$; $\varphi(CO) = 50$, $\varphi(CO_2) = 50$. Let x be the number of CO moles, and y, of CO_2 moles in 100 g of the mixture; then $28x + 44y = 100$.

$$\frac{12(x+y)}{16(x+2y)} = \frac{1}{2};\ x = 1.389;\ y = 1.389.$$

$$\omega(CO) = \frac{1.389 \times 28 \times 100}{100} = 38.89\ (\%);$$

$$\omega(CO_2) = \frac{1.389 \times 44 \times 100}{100} = 61.11\ (\%).$$

Since the number of moles of the gases is identical, their volume percentages are also equal: $\varphi(CO) = \varphi(CO_2) = 50\%$.

26. (4).

27. $CaCO_3 = CaO + CO_2\uparrow$; $CaO + H_2O = Ca(OH)_2$.

28. $CaCO_3$; $Ca(OH)_2 + CO_2 = CaCO_3\downarrow + H_2O$.

29. $SiO_2 + 2NaOH = Na_2SiO_3 + H_2O$;
$Na_2SiO_3 + H_2O + CO_2 = Na_2CO_3 + H_2SiO_3\downarrow$.

30. (4).

$$C + O_2 = CO_2 + 393.5 \text{ kJ} \quad (a);$$

$$C + \frac{1}{2}O_2 = CO + 110.5 \text{ kJ} \quad (b).$$

Further, multiply equation (b) by two and subtract equation (a) to obtain:

$$C + CO_2 = 2CO + 2 \times 110.5 - 393.5;$$

$$C + CO_2 = 2CO - 172.5 \text{ kJ}.$$

31. $CaCO_3 + CO_2 + H_2O \rightleftarrows Ca(HCO_3)_2$; to the left.
32. (1). $SiCl_4 + 4HOH \rightleftarrows H_4SiO_4 + 4HCl$.
33. (2). $2NaHCO_3 + H_2SO_4$ (conc.) $=$ $Na_2SO_4 + 2H_2O + 2CO_2\uparrow$.
34. (3). In the long run, this leads to the formation of large protein molecules, and life is the mode of existence of protein bodies.
35. (3).
36. (2).
37. (4). $2C_2H_6 + 7O_2 = 4CO_2 + 6H_2O$.
38. (2).
39. (4).
40. (4).
41. $COCl_2$.

ν (C) $= 12.1/12.0 = 1.01$ (mole);
ν (O) $= 16.2/16.0 = 1.01$ (mole);
ν (Cl) $= 71.7/35.5 = 2.02$ (mole);
ν (C) : ν (O) : ν (Cl) $= 1 : 1 : 2$, i.e. $COCl_2$.

42. CO_2; Cl_2; $COCl_2$;

$$COCl_2 + 2H_2O \rightleftarrows H_2CO_3 + 2HCl.$$

43. (3).
44. H_2O; $CaO + H_2O = Ca(OH)_2$.
45. $Ca(OH)_2 + CO_2 = CaCO_3\downarrow + H_2O$;
$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$;
$CaCO_3$.
46. $K_2CO_3 + CO_2 + H_2O \rightleftarrows 2KHCO_3$;

$$2KHCO_3 \xrightarrow{T} K_2CO_3 + CO_2\uparrow + H_2O.$$

47. (1).

$$\overset{a-2x}{2COCl_2} \rightleftharpoons C + \overset{x}{CO_2} + \overset{2x}{2Cl_2}.$$

The equilibrium constant can be expressed as:

$K_e = [CO_2][Cl_2]^2/[COCl_2]^2$.

Since the partial pressure is directly proportional to the concentration, the concentration values for the partial pressures of the gases can be substituted in the expression for the equilibrium constant. We find the partial pressures of the gaseous substances that are in equilibrium from the reaction equation:

$p\ (Cl_2) = 2x$; $p\ (COCl_2) = a - 2x$; $p\ (CO_2) = x$

(from the condition). Hence:

$K_e = x\ (2x)^2/(a - 2x)^2 = 4x^3/(a - 2x)^2$.

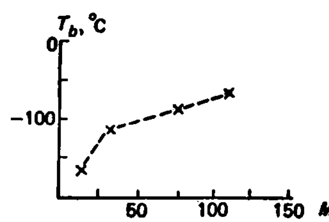
48. $Si + 2Cl_2 = SiCl_4$; $SiCl_4 + 2H_2 = Si + 4HCl$.

49. $CaF_2 + Na_2CO_3 + SiO_2 \overset{T}{=} 2NaF + CaSiO_3 + CO_2$.

50. (2) $3MgO \cdot 2SiO_2 \cdot 2H_2O$;
(3) $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$;
(4) $2ZnO \cdot SiO_2$;
(5) $CaO \cdot Al_2O_3 \cdot 2SiO_2$.

51.

Hydride	T_b, °C
CH_4	—161.5
SiH_4	—111.9
GeH_4	—90
SnH_4	—52



52. Be_2C; BaC_2;

$Be_2C + 4H_2O = 2Be(OH)_2 + CH_4\uparrow$;

$BaC_2 + 2H_2O = Ba(OH)_2 + C_2H_2\uparrow$.

53. 178.4; 238.3. In diamond, the carbon atom is in the state of sp^3 hybridization and, consequently, it has four σ-bonds.
In graphite, the carbon atom is in the sp^2 hybridization and thus has three σ- and one π-delocalized bond. Whence the bond energy of the carbon atoms

in diamond is 713/4 = 178.2 kJ/mole, and the averaged bond energy of carbon atoms in graphite is 715/3 = 238.3 kJ/mole.

54. (2). $\overset{0}{Si} + 2NaOH + \underset{\text{(oxidant)}}{\overset{+1}{H_2}O} = Na_2\overset{+4}{Si}O_3 + 2\overset{0}{H_2}\uparrow$.

55. Mg; $SiO_2 + 2Mg = Si + 2MgO$;
with carbon; $SiO_2 + 2C = Si + 2CO$.

56. (3).

57. (3).

58. (1) $Si + O_2 = SiO_2$;
(2) $SiO_2 + 2NaOH = Na_2SiO_3 + H_2O$;
(3) $Na_2SiO_3 + H_2SO_4 = H_2SiO_3\downarrow + Na_2SO_4$;
(4) $H_2SiO_3 \xrightarrow{T} SiO_2 + H_2O$.

59. (1) $C + O_2 = CO_2$;
(2) $Ca(OH)_2 + CO_2 = CaCO_3\downarrow + H_2O$;
(3) $CaCO_3 \xrightarrow{T} CaO + CO_2$;
(4) $CaO + 3C \xrightarrow{T} CaC_2 + CO$.

60. (1) Photosynthesis;
(2) animal and man digestion;
(3) respiration, fermentation, putrefaction, combustion;
(4) putrefaction, combustion;
(5), (6) decomposition of the remnants of ancient animals and plants under air-free conditions;
(7) exchange of CO_2 between the atmosphere and the ocean basin;
(8) limestone decomposition.

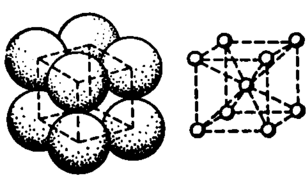
Section 2.5

1. (3). Aluminium concentration in the earth's crust is 8.8% by mass.
2. (3).
3. K, Ca, Li, Mg (density below 5 g/cm^3);
Cd, Co, Mn, Au, Zn, Cu (density above 5 g/cm^3).
4. (1) Osmium (density 22.5 g/cm^3) and lithium (density 0.53 g/cm^3; nearly half the mass of water);

(2) tungsten (T_{melt} = 3410 °C) and cesium (T_{melt} = 28.5 °C), if mercury is neglected (T_{melt} = —38.9 °C);

(3) chromium (you may use it for cutting glass) and cesium (it can be cut with a knife).

5. Calcium. This conclusion is drawn after considering the positions of these elements in the periodic table and the electronic structures of their atoms. Indeed, the ionization energies (in eV) for the atoms of the elements are: K, 4.3; Rb, 4.17; Ca, 6.1; and Sr, 5.6.
6. $LiH + H_2O = LiOH + H_2\uparrow$.
7. (1). The crystal structure of these alkali metals is a body-centered cube.



8. (4).
   1.49 g A reacts with 6.44 g B
   58.71 g A reacts with $2 \cdot A_r$ (B)
   Hence A_r (B) = 126.87. The compound formula reads NiI_2.
9. (4); (4). The melting point for tungsten is 3380 °C.
10. (4).

$$\overset{3.42\ g}{2M} + 2H_2O = 2MOH + \overset{0.488\ litre}{H_2}.$$

$\nu (H_2) = 0.448/22.4 = 0.02$ mole;

ν (M) = 0.04 mole (according to the reaction).

M (M) = 3.42/0.04 = 85.5 (g/mole).

The metal is rubidium.

11. Na_2O_2, peroxide $\left(2Na + O_2 \overset{T}{=} Na_2O_2\right)$;

Fe_3O_4 $(3Fe + 2O_2 \overset{T}{=} Fe_3O_4)$.

12. ω (LiH) = 19.7.

$$\underset{8\text{ g/mole}}{\overset{a\text{ g}}{LiH}} + H_2O = LiOH + H_2\uparrow \quad (1).$$

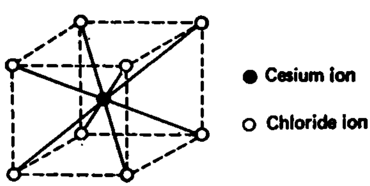
$$\underset{42\text{ g/mole}}{\overset{(0.850 - a)\text{ g}}{CaH_2}} + 2H_2O = Ca(OH)_2 + 2H_2\uparrow \quad (2).$$

The volume (in litres) of hydrogen evolved in the reaction (1) is $a \times 22.4/8$, and that released in the reaction (2), $2\,(0.850 - a) \times 22.4/42$.
Now solve the algebraic equation for a:

$$\frac{22.4a}{8} + \frac{44.8(0.850 - a)}{42} = 1.2, \text{ whence } a = 0.168,$$
$0.850 - a = 0.682$.

ω (LiH) $= 0.168 \times 100/0.850 = 19.7$ (%).

13. Cu_2O. The oxygen mass in the oxide is: $11.66 - 10.36 = 1.3$ (g); Cu_xO_y; $x : y = 10.36/63.5 : 1.3/16 = 0.16 : 0.08 = 2 : 1$; the oxide formula reads Cu_2O.
14. (1).
15. (1).
16.



17. Halogens; $2K + Br_2 = 2KBr$.
18. (3). A decrease in the melting points of the halides of alkali metals from fluorides to iodides is due to a decrease in the stability of these compounds, which depends, in particular, on the ionic distance in the crystal lattice: the larger the distance, the less stable is the halide. Therefore, a regular increase in the ionic radius of an alkali metal on passing from Li^+ to Cs^+ as well as an increase in the ionic radius of a halogen from F^- to I^- causes a regular

increase in the sum of the radii for the cation and anion ($r_+ + r_-$, nm), presented in the table:

	Li^+	Na^+	K^+	Rb^+	Cs^+
F^-	0.201	0.231	0.266	0.282	0.298
Cl^-	0.249	0.279	0.314	0.330	0.346
Br^-	0.264	0.294	0.329	0.345	0.361
I^-	0.288	0.318	0.353	0.369	0.385

19. BiF_3 and BiF_5.

20. (2). 0.6 g of carbon corresponds to 5 g of salt and 2 g of metal, then 12 g of carbon corresponds to $12 \times 5/0.6 = 100$ g of salt A and $12 \times 2/0.6 = 40$ g of metal B.
The salt contains oxygen whose mass is: $100 - (12 + 40) = 48$ g; the metal is Ca, and the salt, $CaCO_3$.

21. (1).

22. (4).

23. (2).

$$\underset{\text{0.142 mole}}{Fe} + \underset{\text{0.164 mole}}{2HCl} = FeCl_2 + H_2.$$

m (HCl) $= 60 \times 0.1 = 6$ g (0.164 mole), ν (Fe) $= 8/56 = 0.142$ (mole).

Complete dissolution of iron in hydrochloric acid requires no less than $0.142 \times 2 = 0.284$ mole HCl, i.e. we have an insufficient amount of HCl. Therefore, even if the Fe^{2+} ion formed is partially oxidized by the atmospheric oxygen to Fe^{3+}, the excess of iron filings will reduce it: $Fe^{3+} + Fe \rightarrow 2Fe^{2+}$; simultaneously, hydrolysis will occur: $Fe^{2+} + HOH \rightleftharpoons Fe(OH)^+ + H^+$, which will be not suppressed in view of no excess of HCl—the hydrolysis equilibrium will not be shifted to the left. Hence, the product is Fe(OH)Cl.

24. $Cu + 2FeCl_3 = 2FeCl_2 + CuCl_2$.

25. (2).

$$\underset{56\ g}{\overset{m\ g}{Fe}} + \underset{73\ g}{2HCl} = FeCl_2 + \underset{2\ g}{\overset{0.25\ g}{H_2\uparrow}}.$$

m (HCl) $= 182.5 \times 0.1 = 18.25$ (g). From the mass of the evolved hydrogen, find the mass of the reacted iron (according to the reaction):

m (Fe) $= 56 \times 0.25/2 = 7$ (g).

Then the mass of the product of the iron oxidation is

$16 - 7 = 9$ (g).

The iron was dissolved with this amount of hydrochloric acid:

$73 \times 0.25/2 = 9.125$ (g) (according to the reaction).

The oxides are: FeO, Fe_2O_3, and Fe_3O_4. In the general case, Fe_aO_b:

$Fe_aO_b + 2bHCl = aFeCl_{2b/a} + bH_2O$.

9 g of the oxide needed $18.25 - 9.125 = 9.125$ (g) of HCl.
Then: $9/(56a + 16b) = 9.125/(2b \times 36.5)$;
$56a + 16b = 72b$; $56a = 56b$, i.e. $a = b$ and the oxide is FeO.

26. (2).

27. (M) Pb; (A) PbO; (B) Pb_3O_4; (C) PbO_2.
The reaction schemes: $Pb + O_2 \rightarrow PbO$; $PbO + O_2 \rightarrow Pb_3O_4$; $PbO_2 \xrightarrow{-O_2} Pb_3O_4$; $PbO + PbO_2 \rightarrow Pb_3O_4$.

28. (2). $2Al + Ca(OH)_2 + 2H_2O = Ca(AlO_2)_2 + 3H_2$.

29. (1). The reaction with zinc yields hydrogen in an amount of approximately 2.5 times less:

$Mg + 2HCl = MgCl_2 + H_2\uparrow$;

$Zn + 2HCl = ZnCl_2 + H_2\uparrow$;

A_r (Mg) $= 24$; A_r (Zn) $= 65$;

$65/24 \approx 2.5$ times.

30. (1). The gas evolving in the interaction of the product of dissolution of the metal in nitric acid with an alkali taken in excess is ammonia. Consequently, one of the products of the metal dissolution in the acid can be ammonium nitrate. Then the reaction

equations in the general form can be presented as:

$8M + 10nHNO_3 = 8M(NO_3)_n + nNH_4NO_3 + 3nH_2O$;

$nNH_4NO_3 + nNaOH = nNH_3 + nH_2O + nNaNO_3$.

Hence the scheme:

$$\begin{array}{ll} 13\ g & 1.12\ litre \\ 8\ M & \rightarrow nNH_3 \\ 8A\ g & 22.4\ litre \end{array}$$

13 g M corresponds to 1.12 litre NH_3

8 A g M corresponds to 22.4n litre NH_3

$A = 13 \times 22.4n/(8 \times 1.12) = 32.5n$.

If $n = 1$, $A_r = 32.5$, such metal does not exist.

If $n = 2$, $A_r = 65$, the metal is zinc.

If $n = 3$, $A_r = 97.5$, such metal does not exist.

The metal is zinc. The reaction equation:

$4Zn + 10HNO_3 = 4Zn(NO_3)_2 + NH_4NO_3 + 3H_2O$.

31. (3). $2Cu + O_2 \rightarrow 2CuO$.

32. (4).

33. (2).

34. (4). Titanium was first obtained in 1875 by the Russian scientist D.K. Kirillov. He reported his evidence in the article *Studies on Titanium.*

35. Mercury, low melting point (—39 °C).

36. Tungsten; copper; aluminium.

37. (3). KO_2. $MX + CO_2 \rightarrow O_2 + M_2CO_3$, where X is oxygen or carbon; however, carbide-CO_2 interaction fails to yield oxygen. In the metal-oxygen compound, 16 g of oxygen correspond to 55% of metal, i.e. $16 \times 55/45 = 19.6$ g of metal, but such an alkali metal does not exist; then $2 \times 19.6 = 39.2$ g (this is potassium); $3 \times 19.6 = 58.8$ g (no metal exists). Thus, the metal is K, and the compound, KO_2.

38. (3).

39. (3). Carat is a unit of fineness for gold equal to 1/24 part of pure gold in an alloy. 24-carat gold is pure. Thus, ω (Au) $= 18 \times 100/24 = 75$ (%).

40. (4). $SO_2 + H_2O \rightleftarrows H_2SO_3 \rightleftarrows H^+ + HSO_3^-$.
41. (1).
42. (1).
43. (3). $2Cu + O_2 = 2CuO$.
44. (3). $2Na + 2H_2O = 2NaOH + H_2\uparrow$.
45. (3).
46. (1).
47. $Al^0 - 3\bar{e} \rightarrow Al^{3+}$ (for example, $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2\uparrow$).
48. (4). $E = +0.80 - (-0.74) = 1.54$ (V).
49. (3), blue vitriol solution; $CuSO_4 + Fe = FeSO_4 + Cu$.
50. 42.75; 57.25.

$$\underset{85.5\ \text{g/mole}}{\overset{x\ \text{g}}{2Rb}} + 2H_2O = 2RbOH + \overset{a\ \text{litres}}{H_2\uparrow};$$

$$\underset{65\ \text{g/mole}}{\overset{(10-x)\ \text{g}}{Zn}} + 2RbOH + 2H_2O = Rb_2[Zn(OH)_4] + \overset{b\ \text{litres}}{H_2\uparrow}.$$

Two cases may be considered.
The first case: all of zinc is dissolved. Assume that x g Rb is contained in the mixture; $(10 - x)$ g Zn.
For 2×85.5 g Rb, 22.4 litres H_2 is evolved
For x g Rb, a litres H_2 is evolved

$a = 22.4 \times x/171$ (litres).

In compliance with the second reaction the volume of the released hydrogen is:

$b = 22.4\,(10 - x)/65$.

$a + b = 1.12;\ \dfrac{22.4x}{171} + \dfrac{22.4(10 - x)}{65} = 1.12$, whence: $x = 10.9$ g.

But this is not the case because the mass of the whole mixture is 10 g.
The second case: the second reaction equation indicates that zinc has not reacted completely. Then the calculation should be performed in terms of RbOH, and the volume of H_2 is:

$b = 22.4x/171;\ 2 \times 22.4x/171 = 1.12$, whence:
$x = 4.275\ (42.75\%)$ Rb; $(10 - x) = 5.725\ (57.25\%)$ Zn.

51. $Ni^{2+} + 2\bar{e} = Ni$ (metallic nickel is deposited);
$Ni^0 - 2\bar{e} = Ni^{2+}$ (anode dissolution of metal).

52. (2).

$$CuCl_2 \xrightarrow{\text{electrolysis}} \underset{63.5\ \text{g/mole}}{\overset{12.7\ \text{g}}{Cu}} + Cl_2\uparrow.$$

$\nu(Cl_2) = 12.7/63.5 = 0.2$ mole. By the reaction, 0.2 mole of chlorine evolved, i.e. 4.48 litres (at STP).

53. (3). Oxygen is an oxidizing agent, $CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^-$.

54. (1). In addition to the metallic form of tin, Sn α (α-tin) (white tin), another modification, Sn β (β-tin) (grey tin), is known, which exhibits a diamond-like structure and semiconductor properties. This crystalline modification is stable at temperatures below 13.2 °C. Grey tin, unlike white tin, is hard and brittle. At low temperature, white tin is found in the metastable state; the presence of a seed crystal of grey tin in white tin favours the transition Sn $\alpha \rightarrow$ Sn β, and the metal converts into a grey powder. The low temperature favours the same process. The conversion rate is increased with decreasing temperature and reaches a maximum at —33 °C.

The conversion occurs more readily when ordinary tin makes contact with that already converted. Therefore this allows inoculation (seeding) of tin objects from each other and propagation of the embrittlement in this way which was called 'tin pest'. This phenomenon should be taken into account on storage of tin reserves.

A third modification of tin, Sn γ, also exists, which is stable at temperatures above 161 °C.

55. (2); (1).

56. (3).

57. (2).

58. (1).

59. (2).

60. (2). Add hydrochloric acid to the powders in the test tubes. Silver does not react. Dissolution of the iron will yield a gas: $Fe + 2HCl = FeCl_2 + H_2$. Iron(III) oxide and copper(II) oxide will dissolve without

evolution of the gas to form:

$Fe_2O_3 + 6HCl = 2FeCl_3 + 3H_2O$ (yellow-brown solution);

$CuO + 2HCl = CuCl_2 + H_2O$ (sky blue solution).

61. Aluminium; iodine; $2Al + 3I_2 \xrightarrow{H_2O} 2AlI_3$.
62. (4). $Fe + CuCl_2 = FeCl_2 + Cu$.
63. (4).

$$\underset{M\ \text{g/mole}}{\overset{13.7\ \text{g}}{M}} + 2H_2O = M(OH)_2 + \underset{22.4\ \text{litres/mole}}{\overset{2.24\ \text{litres}}{H_2}}$$

M (M) $= 13.7 \times 22.4/2.24 = 137$ g/mole, which corresponds to Ba.

64. (3).

$$\underset{63.5\ \text{g/mole}}{\overset{0.1\ \text{mole}}{Cu}} + 4HNO_3 = Cu(NO_3)_2 + \overset{0.2\ \text{mole}}{2NO_2\uparrow} + 2H_2O.$$

ν (Cu) $= 1/2\nu$ (NO_2) $= 4.48/(2 \times 22.4) = 0.1$ (mole),

m (Cu) $= 0.1 \times 63.5 = 6.35$ (g).

$$\underset{56\ \text{g/mole}}{\overset{0.1\ \text{mole}}{Fe}} + 2HCl = FeCl_2 + \overset{0.1\ \text{mole}}{H_2}.$$

ν (Fe) $= \nu$ (H_2) $= 2.24/22.4 = 0.1$ (mole),

m (Fe) $= 0.1 \times 56 = 5.6$ (g); m (Cu and Fe) $= 5.6 + 6.35 = 11.95$ (g).

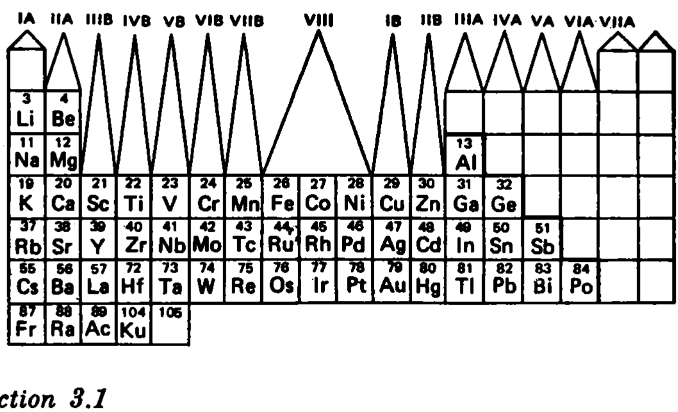
65. (2).
66. (1) d; (2) a; (3) c; (4) b.
67. (3).
68. (1). The higher the acidity of an electrolyte (i.e. the lower the pH value), and the higher the concentration of oxidants in it, the higher is the rate of corrosion; it substantially increases with temperature.
69. Cathodic protection; surface coating with metals; surface coating with varnishes and dyes.
70. (4).
71. (2).

72. (1) Mn; (2) Cr, V; (3) Cr, Ni.
73. Al, 94%; Cu, 4%; Mn, 0.5%; Mg, 0.5%; Fe, 0.5%, and Si, 0.5%.
74. (1) $3HgCl_2 + 2Al = 2AlCl_3 + 3Hg$;
(2) $x\text{Hg} + \text{Al} = \underset{\text{aluminium amalgam}}{\text{AlHg}_x}$;
(3) $4AlHg_x + 3O_2 = 2Al_2O_3 + 4x\text{Hg}$.
75. (2).

$2CrCl_3 + Zn = ZnCl_2 + 2CrCl_2$;
$ZnCl_2 + 4NaOH = Na_2[Zn(OH)_4] + 2NaCl$;
$CrCl_2 + 2NaOH = Cr(OH)_2\downarrow + 2NaCl$.

76. (1) Brass (3) Bronze
(2) German silver (4) Coin alloy

77. Aqua regia; $3Pt + 4HNO_3 + 18HCl = 3H_2[PtCl_6] + 4NO\uparrow + 8H_2O$.
78. (2).
79. (4).
80.



Section 3.1

1. (2); (b); (4); $4NO_2 + 2H_2O + O_2 \rightleftarrows 4HNO_3 + Q$.
2. $2NO + O_2 \rightleftarrows 2NO_2 + Q$; (2).
3. (2). The equation for the reaction of catalytic oxidation of ammonia:
$$4NH_3 + 5O_2 \xrightarrow{\text{catalyst}} 4NO + 6H_2O.$$
The reaction equation suggests that the mole ratio

is 4 : 5 or 1 : 1.25. Thus, according to the problem conditions, oxygen is in excess.

4. $4FeS_2 + 11O_2 = 2Fe_2O_3 + 8SO_2$; $2SO_2 + O_2 = 2SO_3$; V_2O_5; oleum.
5. (2). Solve the problem by the formula: $\omega(H_2SO_4) = m(H_2SO_4)/m$ (of sln); then $m(H_2SO_4) = 500 \times 0.05 = 25$ (g). Convert for 96% solution, using the same formula: m (sln) $= 25/0.96 = 26.04$ (g), i.e. approximately 26 g. It means that in order to prepare a 5% solution of acid we need 26 g of a 96% sulphuric acid and 500 — 26 = 474 (g) of water. Now, since we know the densities of water $\rho(H_2O) = 1$ g/cm^3 and of the acid $\rho(H_2SO_4) = 1.84$ g/cm^3, we can find the volumes: $V(H_2O) = 474$ cm^3 and $V(H_2SO_4) = 26/1.84 = 14.15$ cm^3, i.e. about 14 cm^3.
6. $N_2 + 3H_2 \rightleftarrows 2NH_3 + Q$; 450-500 °C; 15×10^3 kPa, Fe (with Al_2O_3 admixture); (1).
7. $Ca_3(PO_4)_2 + \mathbf{3H_2SO_4} = 3CaSO_4\downarrow + \mathbf{2H_3PO_4}$.
8. $Ca_3(PO_4)_2 + 3SiO_2 + 5C = \mathbf{3CaSiO_3} + \mathbf{5CO} + \mathbf{2P}$.
9. H_2, Cl_2 ($H_2 + Cl_2 = 2HCl$): $2NaCl \text{ (solid)} + H_2SO_4 \text{ (conc.)} \xrightarrow{T} Na_2SO_4 + 2HCl\uparrow$.
10. (3). $SiO_2 + C = Si + CO_2$; admixtures of the carbide SiC.
11. (2). $2NaHCO_3 \xrightarrow{T} Na_2CO_3 + CO_2 + H_2O$.
12. (2).
13. $B_2O_3 + 3Mg = \mathbf{2B} + \mathbf{3MgO}$; (2). $2H_3BO_3 = B_2O_3 + 3H_2O$.
14. (3). $Na_2CO_3 + Ca(OH)_2 = CaCO_3\downarrow + 2NaOH$.
15. $Ca_3(PO_4)_2 + 2H_2SO_4 = \mathbf{2CaSO_4}\downarrow + \mathbf{Ca(H_2PO_4)_2}$.
16. $Ca_3(PO_4)_2 + 4H_3PO_4 = \mathbf{3Ca(H_2PO_4)_2}$.
17. $H_3PO_4 + Ca(OH)_2 = \mathbf{CaHPO_4 \cdot 2H_2O}$.
18. (2).
19. (3).
20. $CO + H_2O \xrightarrow{T} CO_2 + H_2$.

Section 3.2

1. (1) d; (2) b; (3) a; (4) c.
2. (3).
3. (2).

4. (1) $Li_2O \cdot Al_2O_3 \cdot 4SiO_2 + H_2SO_4 \rightarrow Li_2SO_4 + Al_2O_3 \cdot 4SiO_2 + H_2O$;
(2) $Li_2SO_4 + Na_2CO_3 \rightarrow Li_2CO_3\downarrow + Na_2SO_4$;
(3) $Li_2CO_3 + 2HCl \rightarrow 2LiCl + CO_2\uparrow + H_2O$;
(4) $2LiCl \xrightarrow{\text{electrolysis}} 2Li + Cl_2\uparrow$.
5. (3).
6. Al, C, CO, H_2.
7. (3). Aluminium, lying substantially below potassium in the electromotive series, cannot reduce it from the salt melt.
8. (4).

$$\underset{58.5\text{ g/mole}}{\overset{234\text{ g}}{2NaCl}} \xrightarrow{\text{electrolysis}} \underset{23\text{ g/mole}}{2Na} + Cl_2\uparrow.$$

$\nu(Na) = \nu(NaCl) = 234/58.5 = 4$ (mole),
$m(Na) = 23 \times 4 = 92$ (g).
9. Dolomite $MgCO_3 \cdot CaCO_3$. Among the minerals listed, i.e. bauxite $Al_2O_3 \cdot H_2O$, cuprite Cu_2O, gypsum $CaSO_4 \cdot 2H_2O$, dolomite $MgCO_3 \cdot CaCO_3$, and pyrite FeS_2, only dolomite incorporates magnesium. Calcined dolomite ($MgCO_3 \cdot CaCO_3 \xrightarrow{T} MgO \cdot CaO + 2CO_2\uparrow$) is reduced by thermal reduction method in electric furnaces under vacuum at 1200-1300 °C with ferrosilicon (or aluminosilicate) according to the scheme:

$2(MgO \cdot CaO) + Si = Ca_2SiO_4 + 2Mg$.
10. (3). $MgCl_2 \xrightarrow{\text{electrolysis}} Mg + Cl_2\uparrow$.
11. (1) $Mg^{2+} + CaO + H_2O \rightarrow Mg(OH)_2\downarrow + Ca^{2+}$;
(2) $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$;
(3) $Ca^{2+} + H_2SO_4 \rightarrow CaSO_4\downarrow + 2H^+$;
(4) $MgCl_2 \xrightarrow{\text{electrolysis}} Mg + Cl_2$.
12. Ca; Cl_2.
13. (4). Electrolysis of a solution of potassium hydroxide reduces to the water electrolysis:

$$\begin{array}{r|l} 2 & 2H_2O + 2\bar{e} = H_2\uparrow + 2OH^- \\ 1 & 4OH^- - 4\bar{e} = O_2\uparrow + 2H_2O \\ \hline \end{array}$$

$$2H_2O \xrightarrow{\text{electrolysis}} 2H_2\uparrow + O_2\uparrow$$

The amount of hydrogen released at the cathode is twice that at the anode, i.e. $500 \times 2 = 1000$ cm^3.

14. (4). The melting point of Al_2O_3 is 2072 °C; the use of cryolite allows carrying out electrolysis at temperatures below 1000 °C.
15. (1) $Al(OH)_3$; (2) $HAlO_2$.
16. (2).

$$\underset{102\text{ g/mole}}{\overset{1\text{ ton}}{2Al_2O_3}} \xrightarrow{\text{electrolysis}} \underset{27\text{ g/mole}}{4Al} + 3O_2\uparrow.$$

$\nu\,(Al_2O_3) = 10^6/102 = 9807$ (mole); $m\,(Al) = 2 \times 9807 \times 27 \approx 530 \times 10^3$ (g) $= 530$ kg.

17. $Al(OH)_3 + 3NaOH + 6HF = Na_3AlF_6 + 6H_2O$.
18. $ZnCO_3$; ZnS;

$$ZnCO_3 \xrightarrow{T} ZnO + CO_2\uparrow,$$
$$ZnO + C \xrightarrow{T} Zn + CO\uparrow;$$
$$2ZnS + 3O_2 \xrightarrow{T} 2ZnO + 2SO_2\uparrow,$$
$$ZnO + C \xrightarrow{T} Zn + CO\uparrow.$$

19. $Cu_2(OH)_2CO_3 \xrightarrow{T} 2CuO + H_2O + CO_2\uparrow$;

$CuO + H_2 \xrightarrow{T} Cu + H_2O$.

20. $Cu_2S + 2O_2 = 2CuO + SO_2\uparrow$;

$2CuO + Cu_2S = 4Cu + SO_2\uparrow$.

21. (2); $2CuFeS_2 + 5O_2 + 2SiO_2 = 2Cu + \underset{\text{slag}}{2FeSiO_3} + 4SO_2\uparrow$.

$M\,(CuFeS_2) = 183.5$ g/mole; $M\,(Cu) = 63.5$ g/mole.

183.5 g $CuFeS_2$ forms 63.5 g Cu
1000 g $CuFeS_2$ forms x g Cu
$x = 1000 \times 63.5/183.5 \approx 346$ (g) Cu.

22. (4). Anode: $Cu^0 - 2\bar{e} = Cu^{2+}$; cathode: $Cu^{2+} + 2\bar{e} = Cu^0$.
23. (3).

$$\underset{79.5\text{ g/mole}}{\overset{79.5\text{ g}}{CuO}} + H_2 = \underset{63.5\text{ g/mole}}{\overset{x\text{ g}}{Cu}} + H_2O.$$

From the reaction equation one can see that 79.5 g CuO forms 63.5 g Cu.

24. (1).

$$\underset{79.5\ \text{g/mole}}{\overset{x\ \text{mole}}{CuO}} + H_2 = \overset{x\ \text{mole}}{Cu} + \overset{x\ \text{mole}}{H_2O}$$

$$\underset{160\ \text{g/mole}}{\overset{y\ \text{mole}}{Fe_2O_3}} + 3H_2 = \overset{2y\ \text{mole}}{2Fe} + \overset{3y\ \text{mole}}{3H_2O}\ .$$

$\nu\ (H_2O) = 9/18 = 0.5$ (mole).

The set of equations:

$$\begin{cases} x + 3y = 0.5 \\ 79.5x + 160y = 31.9 \end{cases}$$

is solved to yield: $y = 0.1$ (mole); $x = 0.5 - 3 \times 0.1 = 0.2$ (mole). Thus, we have: 0.1 mole Cu and 2×0.2 mole $= 0.4$ mole Fe (see reaction equations). Hence $m\ (Cu) = 0.1 \times 63.5 = 6.35$ (g), and $m\ (Fe) = 0.4 \times 56 = 22.4$ (g), i.e.

$\omega\ (Cu) = 6.35 \times 100/28.75 \approx 22\ (\%)$ and $\omega\ (Fe) = 22.4 \times 100/28.75 \approx 78\ (\%)$.

25. (2). $2CuSO_4 + 2H_2O \xrightarrow{\text{electrolysis}} 2Cu + O_2\uparrow + 2H_2SO_4$.

26. (1) $Fe_2O_3 \cdot H_2O$ (3) Fe_3O_4
(2) Fe_2O_3 (4) $FeCO_3$

27. (2).

Fe_3O_4: $\omega\ (Fe) = 168/232 = 0.724$;
Fe_2O_3: $\omega\ (Fe) = 112/160 = 0.70$;
$Fe_2O_3 \cdot H_2O$: $\omega\ (Fe) = 112/178 = 0.63$;
$FeCO_3$: $\omega\ (Fe) = 56/116 = 0.49$.

Thus, manufacture of iron from magnetite is more favourable.

28. (4). To produce 1000 kg of the alloy one needs:

$1000 \times 95/100 = 950$ (kg) of pure iron.
$M\ (Fe_2O_3) = 160$ g/mole; $M\ (Fe) = 56$ g/mole.
160 kg Fe_2O_3 forms 2×56 kg Fe

x kg Fe_2O_3 forms 950 kg Fe

$x = 1357$ kg Fe_2O_3; the mass percent of Fe_2O_3 in

the ore is 78%, hence, the ore mass is 1357/0.78 ≈ 1740 kg.

29. C, Si, S, P, Mn.

30. (1) $3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$;
(2) $Fe_3O_4 + CO = 3FeO + CO_2$;
(3) $FeO + CO = Fe + CO_2$;
(4) $FeO + C = Fe + CO$.

31. (1) $SiO_2 + 2C = Si + 2CO$;
(2) $MnO + C = Mn + CO$;
(3) $Ca_3(PO_4)_2 + 5C = 2P + 3CaO + 5CO$.

32. (4). FeS is readily soluble in liquid pig iron.
33. (3).
34. O_2, FeO (oxidizing agents); C, P, Mn, Si (reducing agents).
35. $Si + 2FeO = SiO_2 + 2Fe$.
36. CaO; $3CaO + P_2O_5 = Ca_3(PO_4)_2$.
37. (4). Commonly, 0.1-0.2%.
38. (3).

$$\underset{100\ \text{g/mole}}{CaCO_3} = \underset{56\ \text{g/mole}}{CaO} + CO_2\uparrow.$$

100 g $CaCO_3$ forms 56 g CaO
180 ton $CaCO_3$ forms m ton CaO
m (CaO) = 56 × 180/100 = 100 (ton); m (impurities) = 350 − 100 = 250 (g); ω (impurities) = 250 × 100/1000 = 25%.

39. $$\underset{\text{(unpurified)}}{Fe} + 5CO \xrightarrow{T} Fe(CO)_5 \xrightarrow{T} \underset{\text{(purified)}}{Fe} + 5CO.$$

40. (1). M ($Fe(CO)_5$) = 196 g/mole; see Answer 39 for the reaction equation.
Manufacture of 56 kg Fe (pure) requires 196 kg $Fe(CO)_5$
Manufacture of 2 kg Fe (pure) requires m kg $Fe(CO)_5$
$m = 196 \times 2/56 = 7$ kg.
41. N.N. Beketov, 1865; laid a foundation for aluminothermy.
42. (3).
43. (4).
44. $2Al + Cr_2O_3 \xrightarrow{T} 2Cr + Al_2O_3$.

45. (2).
46. Chrome iron ore; $Fe(CrO_2)_2$ (or $FeO \cdot Cr_2O_3$).
47. (2). In ferrochrome, the ratio is Fe : Cr = 1 : 2, i.e.
(2 × 52 + 56) g ferrochrome contains 2 × 52 g Cr
100 g ferrochrome contains m g Cr
m (Cr) = 2 × 52 × 100/(2 × 52 + 56) = 65 (g), i.e. ω (Cr) = 65%.
48. (3).

$$\underset{}{3CaO} + \underset{27\ \text{g/mole}}{2Al} = \underset{40\ \text{g/mole}}{3Ca} + Al_2O_3.$$

Manufacture of 3 × 40 kg Ca requires 2 × 27 kg Al
Manufacture of 100 kg Ca requires m kg Al
m (Al) = 2 × 27 × 100/(3 × 40) = 45 (kg).

49. 3.38.

$$\underset{599\ \text{g/mole}}{Co_3(AsO_4)_2 \cdot 8H_2O} \rightarrow \underset{50\ \text{g/mole}}{3Co}$$

Manufacture of 177 kg Co needs 599 kg ore
Manufacture of 1 kg Co needs m kg ore

m = 1 × 599/177 = 3.38 (kg).

50. V_2O_5; $V_2O_5 + 5Ca = 2V + 5CaO$.

Mass m (O_2) = 1.82 — 1.02 = 0.8 (g); oxide V_xO_y; A_r (V) = 51, A_r (O) = 16; $51x{:}16y = 1.02{:}0.8$; $x{:}y = 0.02{:}0.05 = 2{:}5$, whence V_2O_5.
51. (4).
52. (3). A current intensity of 1 A corresponds to passing of 1 candela per second; a total of 50 × 60 × 20 = 6000 cl has passed through the solutions. Consequently, deposited are:

m (Ag) = 107.9 × 6000/(1 × 96 500) ≈ 6.7 (g);

m (Cu) = 63.5 × 6000/(2 × 96 500) ≈ 2 (g);

m (Au) = 197.0 × 6000/(3 × 96 500) ≈ 4 (g).

53. $TiO_2 + 2C + 2Cl_2 = TiCl_4 + 2CO$;
(2); $TiCl_4 + Mg = 2MgCl_2 + Ti$.
54. Galenite; $2PbS + 3O_2 = 2PbO + 2SO_2$;

$PbO + CO = Pb + CO_2 (2C + O_2 \rightarrow 2CO)$.

55. Cassiterite; (1); $SnO_2 + 2C = Sn + 2CO$.

56. $WO_3 + 3H_2 \xrightarrow{T} W + 3H_2O$.

57. (4).

58. (2).

59. HgS; $HgS + O_2 \xrightarrow{T} Hg + SO_2$.

60. (1) $4Au + 8KCN + O_2 + 2H_2O = \mathbf{4K[Au(CN)_2]} + 4KOH$;
(2) $\mathbf{2K[Au(CN)_2]} + Zn = K_2[Zn(CN)_4] + 2Au$.

61. (3).

Mikhail Vasilyevich Lomonosov (1711-1765). Leading figure in Russian science and literature, known especially for his contributions to natural sciences and his poetry and grammatical writings. Pushkin wrote about him: "A historian, a rhetorician, a chemist, a mineralogist, an artist, and a poet, he tried everything and penetrated through everything."
Lomonosov's works in geology, physics, and chemistry have extended logically into his studies into metallurgy, whose role in the life of his country he estimated so much. He reorganized the St. Petersburg Imperial Academy of Sciences and established a university in Moscow. The Academy appointed Lomonosov professor in 1745 and councillor of Moscow State University in 1757.
His work *276 Notes on Corpuscular Philosophy and Physics* set forth the dominant ideas of his scientific work.

Section 3.3

1. (b); (2).

2. (2).

3. $Na_2CO_3 + CaCO_3 + 6SiO_2 = 2CO_2\uparrow + Na_2O \cdot CaO \cdot 6SiO_2$.

4. $Na_2SO_4 + C + CaCO_3 + 6SiO_2 = Na_2O \cdot CaO \cdot 6SiO_2 + CO\uparrow + SO_2\uparrow + CO_2\uparrow$.

5. 1.6; 7.8; $1.6Na_2O \cdot 7.8SiO_2 \cdot CaO$.

Oxide	*Mass percent, %*	*Molar mass, g/mole*	*Mole number*	*Mole number per 1 mole* CaO
SiO_2	75	60	1.25	7.8
CaO	9	56	0.16	1.0
Na_2O	16	62	0.26	1.6

6. $0.3Na_2O \cdot MgO \cdot 1.4(B_2O_3 \cdot Al_2O_3) \cdot 2.8CaO \cdot 9SiO_2$.

Oxide	*Mass percent, %*	*Mole number*	*Mole number per 1 mole* MgO
SiO_2	54.0	54/60 = 0.9	9.0
Al_2O_3	14.0	14/102 = 0.14	1.4
B_2O_3	10.0	10/70 = 0.14	1.4
CaO	16.0	16/56 = 0.28	2.8
MgO	4.0	4/40 = 0.1	1.0
Na_2O	2.0	2/62 = 0.03	0.3

7. (1) Cobalt(II) oxide;
(2) Chromium(III) oxide;
(3) Manganese(II) oxide;
(4) Iron(II) compounds.

8. (1) $2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl\uparrow$;
(2) $Na_2SO_4 + 2C = Na_2S + 2CO_2$;
(3) $Na_2S + CaCO_3 = Na_2CO_3 + CaS$.

9. (1) $NH_3 + CO_2 + H_2O \rightarrow NH_4HCO_3$;
(2) $NH_4HCO_3 + NaCl \rightarrow NaHCO_3 + NH_4Cl$;
(3) $2NaHCO_3 \xrightarrow{T} Na_2CO_3 + CO_2\uparrow + H_2O$.

10. SiO_2; $2NaOH + SiO_2 = Na_2SiO_3 + H_2O$.

11. $Na_2O \cdot CaO \cdot 6SiO_2 + 28HF = 2NaF + CaF_2 + 6SiF_4 + 14H_2O$.

12. (4).

13. (1) AgCl = Ag + Cl;
(2) Ag + Cl = AgCl.

14. Pyrex; B_2O_3.

15. (3).

16. Sand; clay; limestone;
SiO_2; $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$; $CaCO_3$.
17. Clinker;

$$4CaCO_3 + SiO_2 + Al_2O_3 \xrightarrow{Fe_2O_3} CaSiO_3 + 3CaO \cdot Al_2O_3 + 4CO_2\uparrow.$$

18. $2Ca(AlO_2)_2 + 10H_2O = Ca_2Al_2O_5 \cdot 7H_2O + 2Al(OH)_3$.

19. Ca_3SiO_5; Ca_2SiO_4; $Ca_3(AlO_3)_2$; $Ca(FeO_2)_2$;
$Ca_3SiO_5 + 3H_2O = Ca_2SiO_4 \cdot 2H_2O + Ca(OH)_2$;
$Ca_2SiO_4 + 2H_2O = Ca_2SiO_4 \cdot 2H_2O$;
$Ca_3(AlO_3)_2 + 6H_2O = Ca_3(AlO_3)_2 \cdot 6H_2O$;
$Ca(FeO_2)_2 + aq = Ca(FeO_2)_2 \cdot aq$

20. (6).
21. (3) → (1) → (2).
22. $HOMgO(-Mg-O-)_nMgCl$.
23. Concrete; reinforced concrete.
24. (3).
25. (1) d; (2) c; (3) a; (4) b.
26. (1).

Section 4

1. (II); (4); metals; (c); (b′); lanthanide contraction.
2. 54.95; manganese; MnO; Mn_2O_7.
The first oxide:

$$M_2O_x;\ 2 : x = \frac{0.7745}{A_r(M)} : \frac{0.2255}{16} = \frac{54.95}{A_r(M)} \quad (1).$$

The second oxide:

$$M_2O_y;\ 2 : y = \frac{0.4952}{A_r(M)} : \frac{0.5048}{16} = \frac{15.695}{A_r(M)} \quad (2).$$

Expression (1) is divided by (2) to obtain:

$$\frac{x}{y} = \frac{54.95}{15.695} = 3.5;\quad \frac{x}{y} = \frac{7}{2}.$$

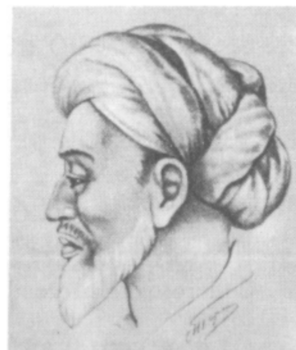
The substitution $x = 2$ in Eq. (1) yields: A_r (M) = 54.95; the metal is Mn; the composition of the first oxide is MnO, of the second, Mn_2O_7.

3. (1). $\nu(Na_2CO_3 \cdot xH_2O) = \nu(CO_2) + 0.1008/22.4 = 0.0045$ (mole).

$M(Na_2CO_3 \cdot xH_2O) = 1.287/0.0045 = 286$ (g/mole).

$M_r(Na_2CO_3 \cdot xH_2O) = 286$; $286 = 106 + 18x$, $x = 10$.

4. Avicenna.



Avicenna (ABŪ 'ALI AL-HUSAYN IBN' ABD ALLĀH IBN SINA (980-1037), the most famous and influential of the philosopher-scientists of Islām. Born in Bukhara, Persia. Avicenna's youth was spent in the company of the greatest sages of his time. He became accomplished in all the sciences and arts and had a wide reputation as a physician and administrator. In Hamadan, he composed his *Book of Healing* a vast philosophical and scientific encyclopaedia, and the *Canon of Medicine*, which is among the most famous books in the history of medicine.

5. (4). The conclusion is drawn from a comparison of the relative molecular masses of the gases.
6. (1).
7. (2).
8. (4).
9. (1).

In KCl:	$\omega(K) = 39/74.5 = 0.524$;
In K_2SO_4:	$\omega(K) = 78/174 = 0.448$;
In $KHSO_4$:	$\omega(K) = 39/136 = 0.199$;
In KNO_3:	$\omega(K) = 39/101 = 0.386$.

The calculations prove that potassium chloride shows the largest mass percent of potassium.

10. (2).
11. $S_4O_6^{2-} < I_2 < S_2O_8^{2-}$;
(1) to the left; (2) to the right; (3) to the right.
12. (2); (b); $FeCl_3$.

13. $Ni(CO)_4$;
(1) ... this structure results from the involvement of four sp^3 orbitals for bond formation;
(2) ... low boiling point;
(3) ... bonds that are formed involving four sp^3 orbitals exhibit a distinct steric orientation and a covalent character;
(4) ... its symmetric tetrahedral molecules are nonpolar.
14. (1). The greater the polarization of the two ions, the more covalent is the bond between them (E—O) (and the less ionic), which accounts for a decrease in thermal stability of the carbonates in the process:

$$\begin{matrix} E-O \\ E-O \end{matrix}\!\!>\!C=O \rightarrow \begin{matrix} E \\ E \end{matrix}\!\!>\!O + CO_2\uparrow.$$

15. CaH_2; H_2Te; GeH_4; BiH_3;
CaH_2. Due to the greatest difference in the values of the electronegativities for hydrogen and calcium.
16. (3); (b).
17. (4).
18. (2). Cation-exchange resin entraps calcium ions from the solution and thereby water is decalcified. This is the method for removing the hardness of water.
19. (2). The earth's crust (lithosphere) is the solid surface of the earth about 20 km deep. It mainly comprises

Oxide	Mass percent of oxide, %		An asterisk denotes discrepancy in the compositions
	in the moon ground	in the earth's crust	
SiO_2	41-46	44-53	
TiO_2	2-12	0.9-3.2	*
Al_2O_3	7-14	13-19	
FeO	18-12	7-14	*
CaO	8-12	8-12	
MgO	7-16	4-10	
Na_2O	0.2-0.5	1.8-3.8	*
MnO	0.21-0.29	0.09-0.3	

a silicate matrix which includes rare regions of other substances of high concentration. Below are given some comparative data on the concentration of various oxides in the moon ground and in the most widespread earth rocks.

20. 3.04×10^{-1}; traces; 0.2; 0.2; traces. The first three test tubes show the same pressure. This means that it is the equilibrium pressure, i.e. it is independent of the amount of salt and of the addition of the relevant oxide to it:

$FeCO_3$ (solid) $\rightleftharpoons$ FeO (solid) + CO_2 (gas);

$K_e = p\,(CO_2) = 4254.6$ kPa.

The same is true of the other three test tubes:

$MgCO_3$ (solid) $\rightleftharpoons$ MgO (solid) + CO_2 (gas);

$K_e = p\,(CO_2) = 3.04 \times 10^{-1}$ kPa.

The equilibrium pressure in the system $FeCO_3$—FeO—CO_2 is approximately 10^4 times that in the system $MgCO_3$—MgO—CO_2. Consequently, when all these substances are in contact, the reaction of iron carbonate decomposition shifts to the right. Carbon dioxide is bound by magnesium oxide almost completely.

Thus, the pressure in the run 7 at the temperature T will amount to 3.04×10^{-1} kPa. An approximate composition of the solid phase in the run 7 is: $MgCO_3$, 0.2 mole and FeO, 0.2 mole (with traces of MgO and $FeCO_3$).

21. (4).

22. NH_4Cl (solid) $\rightleftharpoons$ NH_3 (gas) + HCl (gas);
33.43. Since ammonium chloride is a solid substance, $K_e = [NH_3][HCl]$, whence $[NH_3] = [HCl] = \sqrt{K_e}$. Since all the ampoules are heated to the same temperature, the pressure in them will be independent of the amount of the solid substance, i.e. of the number of moles of ammonium chloride. Therefore it will be the same in all the ampoules, i.e. 33.43 kPa.

23. (1) $4NH_4ClO_4 \xrightarrow{T} \mathbf{4HCl + 6H_2O + 2N_2 + 5O_2}$;

(2) $(NH_4)_2SO_4 \xrightarrow{T} \mathbf{2NH_3 + H_2SO_4}$;

(3) $2(NH_4)_2S_2O_8 \xrightarrow{T} \mathbf{4SO_2 + 2N_2 + 8H_2O}$;

(4) $NH_4NO_2 \xrightarrow{T} \mathbf{N_2 + 2H_2O}$.

24. (4). If the problem conditions have included the volume of the evolved hydrogen (say, 1.12 litres at STP), the solution would have been (mercury does not react with hydrochloric acid):

$2Na + 2HCl = 2NaCl + H_2\uparrow$ (a);

$2Al + 6HCl = 2AlCl_3 + 3H_2\uparrow$ (b).

The mass of sodium and aluminium is 5.48 — 4.02 = 1.46 (g). Let the amalgam contain x g of sodium, then the aluminium mass is (1.46 — x) g. The volume of hydrogen evolved in the reaction (a) is $22.4x/(2\times23)$ and that in the reaction (b), $3 \times 22.4\ (1.46 - x)/54$.

$$\frac{22.4x}{46} + \frac{3\times22.4(1.46-x)}{54} = 1.12.$$

Divide by 22.4 to obtain:

$$\frac{x}{46} + \frac{3(1.46-x)}{54} = 0.05, \text{ whence } x = 0.92 \text{ g (Na)};$$

$(1.46 - x) = 0.54$ g (Al).

$$\omega\ (\text{Na}) = \frac{0.92\times100}{5.48} = 16.8\%;$$

$$\omega\ (\text{Al}) = \frac{0.54\times100}{5.48} = 9.8\%.$$

the balance is mercury (73.3%).

Now, if an extra condition is the volume of the evolved hydrogen (1.12 litre), the answer (1) is correct.

25.

$M_2S_2O_3$	(2)	(6)	(7)
$M_2S_2O_7$	(3)	(4)	(8)
$M_2S_2O_8$	(1)	(5)	(9)

(4) $2MHSO_4 \xrightarrow{T} H_2O + M_2S_2O_7$;

(5) $2MHSO_4 \xrightarrow{\text{electrolysis}} H_2 + M_2S_2O_8$;

(6) $M_2SO_3 + S = M_2S_2O_3$;

(7) $AgBr + 2M_2S_2O_3 = M_3[Ag(S_2O_3)_2] + MBr$;
(8) $M_2S_2O_7 + 2MOH = 2M_2SO_4 + H_2O$;
(9) $2MnSO_4 + 5M_2S_2O_8 + 8H_2O = 2MMnO_4 + 4M_2SO_4 + 8H_2SO_4$.

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GENERAL CHEMISTRY IN FORMULAS, DEFINITIONS, AND DIAGRAMS

Edited by **V. Tikavy**, Cand.Sc. (Chem.)

All the information required to study a course in general chemistry has been summarized and systematized very concisely in the present reference book. The basic concepts, laws, and factual data are presented in the form of brief definitions (often with the essential explanations), formulas, tables, diagrams, and illustrations. This way of treating the material enabled the authors to include a large volume of reference data in a convenient form for use and comparison, for systematization of the acquired knowledge and its consolidation.

Besides being a valuable supplement to a fundamental textbook in general chemistry for college students not majoring in chemistry, for secondary school teachers, and technical school students, the present book will be very helpful for both persons studying the theoretical fundamentals of general chemistry and those interested in solving problems and performing experimental work.